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A Reference Handbook

OF

THE MEDICAL SCIENCES

EMBRACING THE ENTIRE RANGE OF

SCIENTIFIC AND PRACTICAL MEDICINE

AND

ALLIED SCIENCE

BY VARIOUS WRITERS

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Embryotomy.—The term embryotomy is applied to those destructive operations on the unborn child by means of which its mass is diminished so as to facilitate delivery in the presence of a dystocia. Ordinarily the procedure refers to the removal of the fetal viscera through an opening in the thorax or abdomen (evisceration), or to instances where it is necessary to sever the head from the body (decapitation). With the increase in the number of operative deliveries by cesarean section and pubiotomy, the number of cases in which embryotomy is necessary has largely declined, but there are still a considerable proportion of instances of neglected labor, dystocia due to malposition, or fetal monstrosities, in which one or the other procedure is required. It is hardly necessary to insist that these operations should never be done on the living child.

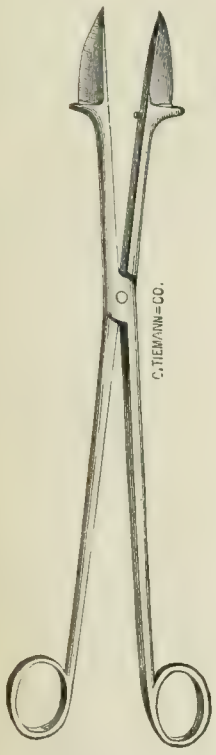

Fig. 2026.—Smellie's Perforator.

Fig. 2027.—Decapitating Hook.

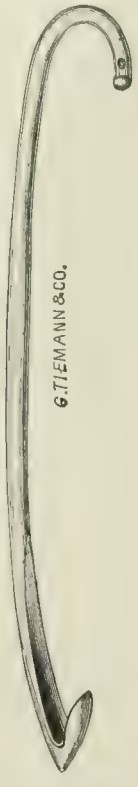

Fig. 2028. Blunt Hook and Crotchet.

Indications.—*Decapitation* is the procedure which is the more frequently employed. It is indicated particularly in neglected transverse presentations, in which a shoulder has become firmly impacted in the pelvis and the uterus, being usually in a state of tonic contraction, contraindicates version on account of the danger of rupture. The child is often dead in these cases but where the heart sounds are strong and the mother's condition warrants the same, abdominal cesarean section with or without hysterectomy should always be considered. Where the child is dead, however, and a version cannot be done, the mutilating operation should not be delayed, as delay increases the danger to the mother.

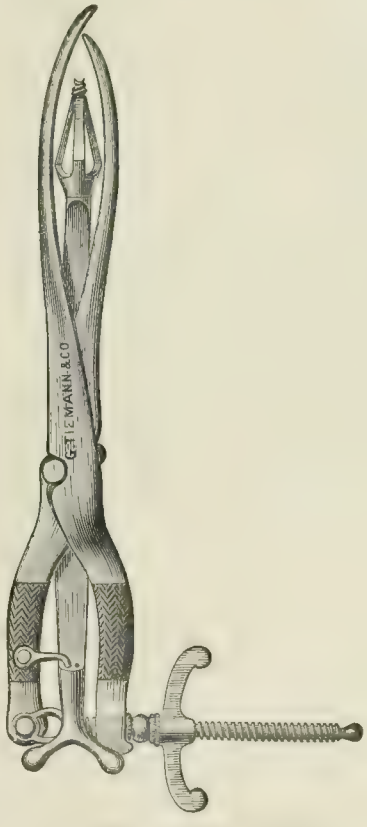

Fig. 2029.—Tarnier's Basiotribe.

Evisceration, although more rarely employed, must be considered in cases of large children or monstrosities in which a transverse presentation occurs and

the thorax or abdomen is fixed over the pelvic brim in such a manner that the neck cannot be reached for the performance of a decapitation.

Technique.—For the performance of *decapitation* a blunt or sickle-shaped hook is required, and in addition a pair of strong, blunt-pointed scissors should be provided. The patient is prepared as for any other major obstetrical operation, the bladder and rectum are thoroughly emptied, and the anesthesia is preceded by a hypodermic of morphine, one-quarter grain, with atropine, one one-hundredth grain. The opiate avoids an excessive amount of the anesthetic and relieves to some extent the tonic contractions of the uterus. The patient should be anesthetized in

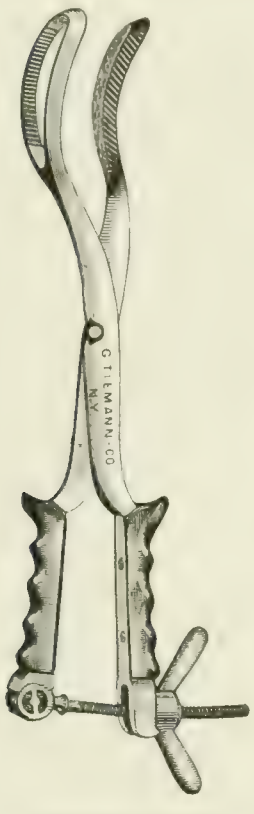

Fig. 2030.—Simpson's Cephalotribe.

Fig. 2031.—Braun's Cephalotribe.

the prone position with ether, or gas and ether if it is procurable. After anesthesia is complete the lithotomy position should be resorted to and the vulvar preparation, including shaving and scrubbing or dry shaving with the application of a five per cent. tincture of iodine, be completed. After draping the patient with sterile sheets, a thorough exploration should be made and the location of the fetal head and neck definitely determined, care being taken not to exert undue force during the introduction of the fingers or hand through the cervix. If the cervix is not completely dilated this should be slowly and carefully done by the manual method. After the neck is located the sickle-shaped hook is introduced and passed around the neck by the aid of the fingers of the free hand. Great care is necessary during the performance of this step in order to avoid injuring the lower uterine segment with the instrument. The child's head is severed from the body with a saw-like movement and the latter is then extracted by traction on the arm. Fortunately in many of these cases the arm is already prolapsed and can be used as a tractor to put the neck on the stretch during the decapitation. In other cases it would be advisable to deliver the arm and employ it for this purpose. If there is any difficulty encountered in extracting the body after the head has been severed the clavicles and thorax may be cut through with the scissors and the viscera evacuated in order to reduce the size of the trunk. Great care should be taken by the operator to avoid lacerating the maternal soft parts with the sharp ends of the cut bones and likewise the operator's own fingers and hands. After the trunk is delivered the head may be expressed by manipulations similar to the Credé delivery of the placenta or if unsuccessful, the hand may be introduced into the uterus, a finger inserted into the mouth of the child and the head thus extracted or brought down where it can be seized and delivered with forceps. Occasionally the head cannot be delivered until it is first crushed after perforation. In place of the sharp hook, Braun's blunt hook may be employed to disarticulate the cervical vertebræ and if any resistance is offered by the soft parts the scissors may be used to cut through the same. This procedure is not as readily carried out as that with the sharp hook.

For the performance of an *evisceration* a pair of long blunt-pointed scissors is necessary, by means of which the thorax or abdomen is entered after making traction upon the trunk with the prolapsed arm. If the anterior thoracic wall presents it is advisable to excise the sternum together with the adjacent ribs and through the opening to deliver the thoracic viscera with the assistance of a sponge-holder or similar instrument. The diaphragm can then be cut through and the abdominal viscera likewise extracted. In most cases it will be found that the delivery cannot be completed until a decapitation has been done, but as the size of the trunk is diminished by the evisceration, the neck can as a rule be more readily reached with the sharp hook.

Hemorrhage after these operations, particularly if the mother has been subjected to a long labor with more or less tonicity of the uterus, is very common and a satisfactory and permanent uterine contraction should be provided for by guarding the fundus, expressing the placenta completely together with all clots and keeping the patient as quiet as possible. Ergot by mouth or hypodermic is advisable. All lacerations of the perineum and extensive ones of the cervix must be immediately repaired. The chances for septic infection are increased by the necessary manipulations and this fact should be known and guarded against.

George W. Kosmak.

Emetics.—An emetic in the narrow sense is some substance which can induce vomiting promptly and safely. Emetics formerly had great vogue in therapeutics, but gastric lavage has probably displaced them to a large extent, for example, in gastric stasis.

Emetics act either locally on the gastric mucosa, or generally, through subcutaneous injection. In either case the result is due to stimulation of the vomiting center.

Emetics are used largely as first aid household remedies; for example, in cases of ingestion of supposedly dangerous articles—in fact, under the very circumstances that the stomach strives to expel an unwelcome substance. The favorite emetics for this purpose are mustard water (two teaspoonfuls to the cupful,) and salt water (the latter contraindicated in sublimate poisoning). The practitioner in this simple class of cases usually relies upon zinc sulphate, from five to twenty grains dissolved in water, because it acts quickly and without nausea.

There are three emetics which stand out above all

others in efficiency and trustworthiness, and which act at least in part directly upon the vomiting center. These are tartar emetic, ipecacuanha (including emetine), and apomorphine. The first named, in addition to its emetic properties is a severe depressant of the circulation, which no doubt renders it nauseating. It may set up a persistent hyperemia which itself requires treatment. It should be regarded as a survival of heroic medication, to be used only when nothing else is available. For a detailed account of ipecacuanha and apomorphine the reader is referred to the special articles on those subjects.

In regard to minor emetics to be used if others are not available, a number have long been in vogue, such as alum, sulphate of copper, carbonate of ammonia, etc. Many nauseating and acrid drugs readily cause vomiting. The further we get away from the standard emetics the more we encounter either sluggish or uncertain action or injurious by-effects. The emetic dose of many substances is as a rule very much larger than the habitual single dose. But if vomiting is due merely to the taste of a remedy, the size of the dose may make little difference.

At the present day the chief use of emetics is in poison cases, and perhaps in obstruction of the respiratory processes in children. Generally speaking an emetic, to possess any value here must be given with great promptness. If the case be one of corrosive mineral poisoning it is usually too late to use an in emetic.

Emetics are seldom contraindicated outright but in any acute abdominal inflammation we should hesitate to use them. In poisoning cases, home remedies, such as zinc sulphate, may be used as first aid, and the earlier they are given the better. Owing to the character of narcotic poisoning in which prevention of absorption is everything, the one strictly indicated remedy is apomorphine, by hypodermic injection. The dose and time of exhibition have been the source of much controversy. If given too late or in too large dose it may produce very untoward effects. In alkaloidal poisoning in the later stages its exhibition would be worse than useless. Many accidents have followed the use of medicinal doses and authors have a way of evading the safe emetic dose. Jurasz fixes it at one-twelfth to one-sixth grain for adults, and half of this for children.

Ipecacuanha (and emetine its derivative), the best known of the emetics, is notable for its slow, even action, and from the fact that its action is not protracted beyond the desired effect. The dose varies very greatly. In other words, the personal equation is considerable. If the average subject requires gr. x. others may require as low as gr. ii or as high as gr. xx. It seldom acts within 20 or 30 minutes. Emetine is given in the same dose as apomorphine ($\frac{1}{12}$–$\frac{1}{6}$ gr.) but exhibits the same deliberateness of action as ipecac. The question arises, has not ipecacuanha outlived its usefulness? The answer is that the drug is peculiarly suited for simple evacuation of the stomach in the young, delicate, and aged, and in any other condition when haste is not necessary. Ipecacuanha is kept in the family medicine chest, not only for its superiority as an emetic in acute indigestion of children, but to avert the accumulation of secretions in the bronchi when haste is not required. If the obstruction of the respiratory passages develops suddenly and is compact, as in the case of croup or foreign bodies, ipecac can be of minor avail, while apomorphine may save life But. ipecac takes precedence over all other internal emetics—in fact, no other should be employed. In rare cases of failure of apomorphine to act, ipecac may still be given. Apomorphine and emetine are the sole drugs to use when swallowing is impossible, notably in patients under narcosis, and of the two apomorphine is much preferred for the purpose.

EDWARD PREBLE.

Emetine.—See *Ipecacuanha.*

Emmanuel Movement.—A characterization of a type of social betterment activity through the cooperation of church work with medicine and put into practice in Emmanuel Church at Boston, hence called the Emmanuel Movement. It is deserving of mention as one of a number of similar attempts which have a laudable purpose, but which through lack of knowledge of coordinate activities being done by others is apt to pass into oblivion after a career of which the length and usefulness will be determined largely by the personality of the prime movers, and the adaptability of means to ends. A brief discussion of its features may be worth while in view of many similar endeavors now in course of, or about to be put into, activity, particularly in the fight with mental disorders—*i.e.* the mental hygiene movements. Only the roughest outlines can be sketched. In primitive societies the chief man of the clan is all powerful. He is the king. In him reside all the hopes and fears, the wishes and doubts of his subjects. Just what his various attributes are cannot be even hinted at here. The studies of Tyler, Frazer, and others on primitive cultures must be consulted. He is among other things doctor, lawyer, and minister. He controls the forces of nature, and if he does not, certain primitive peoples kill him, in order to get one who does. Among others, since only young vigorous men can do all things, they have a new king nearly every day; this being hard on the tribe, however, has to be modified somewhat. At all events the sense of power of the individual is transferred to his chief. He represents the all-macht the "all power" of the egotism of the individual unconscious psyche, which has always and continues to play so important a part in human affairs. Little by little, in the development of human culture, separations of function took place, the individual projected his "all-macht," his sense of importance, upon the king and perhaps upon the medicine man, which latter, among many primitive peoples, is the king, or one step removed from the king. His duty is to keep sickness away, and he receives the same rewards and punishments as the king according to his success or lack of it as judged by the folk lore of the tribe. The king still hung on to the property rights—he remained the lawyer. He might relinquish health and soul matters to others, but he would not relinquish his legal prerogatives. Many thousands of years had passed in human culture before doctor, lawyer, and priest became separate groups in the social body with fairly separate territories. Property rights were fought for by the legal and priestly class, but health situations became of less and less importance, especially as men and women could be bred, or stolen, as slaves and used to create property. For a long time in the history of Europe Emperors and Popes were alternately on top or underneath. To understand the marshalling of human motives which brought this about—tended to perpetuate it—would take one too far afield, but at all events medicine rarely entered into the problem, except that the chief weapon of the religious group was the animistic spiritism of the people; their heritage of beliefs from their primitive beginnings; their ego projections of the power of the forces of the unknown. They were afraid of themselves; struck dumb at the miracle of their own being, hence the power that could create and destroy was something to be greatly feared and propitiated. The expression of this attitude toward the world was the religious spirit. Its organization for definite purposes of civilization and culture was the work of the organized church.

With the growth of science since its great beginnings in the thirteenth century, so far as the high lights of culture are concerned, much of this animism has been modified, and the fears and dreads of mankind, so far as sickness is concerned, have become much more concrete and comprehensible. It is no longer a miasm from Pandora's box. It is a mosquito or a minute parasitic plant, or some other tangible thing

and little by little the all-macht of the individual has been transferred more and more upon the physician until he stands justified in all of the faith of the primitive medicine man. He knows what is the matter, even if it cannot be helped. He is in touch finally with reality, and knows if it is cure or endure. This is only partly true, however, and for the few rather than for the many. There are problems still—more than ever—but the accomplished work is enormous. In the mental sphere, however, there is an immense task before the physician. Two thousand years of medical history are rich in what has been done, but poor in view of the ideal to be achieved. The problems of mental science are complex beyond conception, and yet mankind has the same naive conception toward them that the ancient primitive man had toward physical science. The laymen is in the same attitude of animism toward mental problems as his savage cave dweller ancestor was toward physical ones. To-day, judges on the bench, ministers in the pulpit, bankers in the counting houses believe that they can beat a mental idea out of an individual, or of a society, in precisely the same way that an Australian bushman tries to beat a physical disease out of a bush with tom-toms. Politicians build jails, juries electrocute human beings, legislatures make laws about prostitution, and States legislate about human instincts, etc., etc., and similar mummeries in the twentieth century which are not one whit more enlightened than the methods by which primitive savages handled physical facts in the stone age.

In other words, the tyranny of the commonplace, the naive beliefs in simple causes, in empty formulæ, are exactly similar for mental facts as they used to be for physical ones. That is so far as the layman is concerned, and ordinary intelligence so called, makes every one not having special knowledge a layman. Even many a so-called philosopher has his horse chestnut in his pocket; his amber beads about his babe's neck; his knocking wood, not sitting with thirteen formulæ; and thousands of similar superstitions, from which medicine itself is far from being purged.

One constantly hears the socialistic plaint that the rich are getting richer, the poor poorer. This is a truth, but only from one attitude of mind, *i.e.* the possible contrasts between wealth and poverty are more and more striking. This is also true for the wealth of medical science, the gap between the knowing and the not knowing is getting wider and wider. So is it in all growing accomplishment. This is the great criterion of advance. It is well with the world when it is so. The pseudoreformer, the revolutionist, the anarchist would level all men to the same level and destroy progress. Each by his egotism, his hatred or his lust would project his all-macht and destroy that which he himself did not possess. His god is like himself. He is it.

Thus the principle of striving, of competition, the struggle between egoism and altruism goes on with constant compromises, which mean evolution.

All this seems a long way from the Emmanuel Movement, but it is not, for this movement in its ideal aspects represents the striving of the principle of Christianity to heal the sick, especially the mentally sick. The spirit of organized religion having less and less to combat animistic superstitions regarding the physical in nature—there is some prayer for rain, accompanied by much cannon shooting still going on—turns more and more to the relief of human unhappiness and hence evolves charitable work. Mental ills great and small are very numerous and doctors cannot cope with them all. They are too busy with easy problems and have no time to cope with difficulties which will not feed them. Hence, such problems have been taken up by the organized charitable workers acting through religious channels, in our present state of cultural evolution. This is the cause of the Emmanuel Movement seen as an attempt to relieve suffering humanity, through a combination of medical and religious activities. This very expression of endeavor is in absolute contrast with that of the pseudoreformer, the revolutionist, the anarchist. Here the great sublimation of egoism, of hatred, and of lust, through the expression of altruistic Christian principles, is in reality a part of an evolutionary program which builds culture. This is, as has been said, the ideal. Possibly so far as the working of such a system is concerned it has practical defects. If so then it should be the endeavor of those interested to improve rather than to destroy. The chief defects thus far revealed have been the lack of medical training of the religious worker. There has been that naive simplicity toward the interpretation of mental facts which has been spoken of. Enthusiasm and altruistic zeal has been thought a sufficient compensation for technical knowledge. The human machine has been thought of entirely too crudely, especially that master hand in it, that free spirit of evolution, the nervous system, toward which crudity of apercu even the doctor has very largely contributed. The special training of the priestly class, through its daily dealings with matters termed spiritual, has engendered a little of that cameradie with the great unknown, if it may be so lightly expressed, and special privileges and special powers seem to be theirs by right of endowment, if not for the asking. Here again one meets with that animism spoken of previously—that belief of the individual in the all power in his own ability to perform the miracle, which is an expression of his unconscious wish—his feeling attitude toward the élan vital.

But mental disturbances, hysterias, compulsion neuroses, jealousies, distorted human tastes, alcoholic tendencies, antisocial impulses—these are human character anomalies which have taken many, many years to bring to expression in the most complex of all structures known in nature. They cannot be dealt with from the animistic point of view any longer—for all grades of culture. There are, it is true, many of the lowly and simple minded—perhaps the majority—for whom "authority" is their saving protection. The "big chief" way is still the best way of obtaining self control; but there are many others who require a more developed philosophy of life. The Emmanuel Movement is one of the phenomena of trying to find a way, but on a forward path. It does not deny reality as do many other more primitive movements. Sickness is real and has determining causes and can be understood. Denial of reality belongs to the days when Joshua commanded the sun to stand still. The crude Australian savage may have it "put over him," in which respect he is on a par with the Christian Scientist; but the really intelligent human being of the twentieth century has left that stage of Phœnician mythology, that Chaldean astrological interpretation of an eclipse which the Hebrew writers took over as a tale and gave it a materialistic setting as an historical event.

There are a large number of primitive religious-medical systems which still preach animism for mental phenomena, but the Emmanuel Movement has made an attempt to rid itself of such conditions, even if it has not grasped the value of empirical knowledge of the neuroses and psychoses. This will come about for mental ills when the moneys spent by religious organizations on physical ills are also spent in those much more culturally valuable channels, the alleviation of mental ills. Thus far the State and the Catholic Church chiefly have attempted the task. The Mental Hygiene Movement is the first organized private effort. It would represent a far step in the evolutionary pathway to see organized religion pass on to the spiritual plane in occupying itself with the disordered psyche of mankind by more extended organized efforts of which the Emmanuel Movement is but a single expression.

SMITH ELY JELLIFFE.

Emmenagogues.—The term emmenagogue is applied to any remedy or indeed any resource whatever which normalizes the menses. Since the majority of these act by exciting or strengthening uterine contractions, they merge into another class of drugs or resources which induce contractions of such strength that the contents of the uterus are expelled, a subject, of course, which inheres in labor. Substances of this second class were long known as ecbolics, but in more recent years have been termed oxytocics or agents which intensify normal uterine contractions. This term emmenagogue must be understood in two senses, first, general or indirect, and second, direct or specific emmenagogues, the latter having a selective action on the uterine contractions.

Specific Emmenagogues.—Any emmenagogue which acts by inducing uterine contractions in small doses is naturally an ecbolic when given in excess. A number of these agree in their botanical or chemical nature, since they contain pungent oils (apiol, rue, tansy, savin, pennyroyal). The principal direct emmenagogues are ergot, oxalic acid, apiol, binoxide of manganese, santonin, eumenol, indigo, aloes, permanganate of potassium, turpentine, cantharides, myrrh, rue, savin, tansy, pennyroyal, guaiac, cimicifuga, saffron, cotton-root, quinine, pulsatilla, water pepper, serpentaria, aconite, sage, chamomile, and blue cohosh. It is a fact, however, that the chief physiological oxytocics have little or no vogue as emmenagogues.

This form of emmenagogue, however, despite its popular reputation, is not much heeded by the practitioner, who is sceptical as to the efficacy of such substances. To restore menstruation for the nonce by a combination of drugs which have to be repeated each month is not scientific. We must seek to discover the cause.

Indirect Emmenagogues.—The gynecologist thinks first, of course, of mechanical impediments, developmental defects, etc., which may require correction. Next in order, perhaps, come anemia (especially from tuberculosis), chlorosis, and other blood states. From this viewpoint iron and arsenic represent our chief indirect emmenagogues, for they no doubt normalize the menstruation in many girls.

Equally useful are physical remedies—the application of simple hydrotherapeutic measures, notably the hot sitz bath, the hot foot bath—which act simply by causing congestion of the pelvic viscera. These are naturally used in association with drug remedies as indicated.

Exercise, especially walking often has a salutary effect. Of great value is the practice of stimulating the functions of accessory organs, notably the intestinal and urinary systems. Whether the effects come about from stimulating the nearby organs, or in some reflex fashion, the fact remains of the common use of purgatives, notably aloes, and of substances which irritate the genitourinary system, such as cantharides and turpentine. The use of all such substances is non-scientific, although the bowels must be kept clear. In recent years yohimbin, from its known action upon animals, has been recommended as an emmenagogue which exerts its action on ovulation. Its field must be narrow. It is usually given in advance of the expected period.

From what has been said it may be inferred that emmenagogues are not an essential resource of legitimate practice. They are lay remedies or apothecaries' remedies, and are essentially palliative. We must not lose sight of the fact that the practitioner is in doubt about the ethics of these cases, and always suspects a possibility of concealing conception. If a patient states that she has skipped but a single period, he may distrust her and usually does. EDWARD PREBLE.

Emollients (from Latin *emollire*, to soften) are substances which tend to soften, relax, and protect the parts to which they are applied. As a rule they are fatty and have very little, if any, real medicinal activity; but this lack of active medicinal virtue in no way detracts from their therapeutic value. Emollients are "for outward application" only. Substances of a similar kind, but for *internal* use, are called demulcents, and these two terms must be kept distinct. Demulcents are for mucous membranes; emollients for the skin. (See article *Demulcents.*)

ACTION AND USES.—The action of emollients is almost entirely mechanical; by their moisture and warmth they cause the blood-vessels to dilate, and with relaxation of contractile tissues pressure on the nerves is lessened, and thus the tension and pain in an inflamed part are relieved. Emollients also exert a *protective* influence over inflamed surfaces which would otherwise suffer from friction and even from the oxygen of the air; in cases in which the skin is broken, or the epidermis stripped off, the process of repair can go on without let or hindrance under the protective covering of an emollient. The judicious use of emollients is also responsible for the exclusion of many pathogenic organisms which would otherwise find an easy entrance through a broken skin, and which, having once gained admission, would do more than ordinary harm in tissues whose powers of resistance are already enfeebled. Without emollients wounds, burns, and superficial inflammations would heal but slowly; by emollients the skin is often preserved from cracks, chaps, and fissures, and should these unfortunately supervene emollients are the best remedial agents we have. The application of emollients to those surfaces of the body which come in contact, as the thighs, will lessen the friction and increase the comfort. Emollients also tend to prevent bed-sores and heal blisters; and they are useful in some forms of skin diseases, such as eczema.

List of Emollient Substances.—The chief are: Almond oil, cacao butter, castor oil, cold cream, glycerin, goose grease, lanolin, lard, liniments, linseed oil, neatsfoot oil, olive oil, paraffin, petrolatum, or vaseline, soap, spermaceti, and suet. Care must be taken to avoid using *rancid* fat or oil, for this would act as an irritant, and do more harm than good. Other substances, as collodion, white of egg, etc., act as *protectives*, but are not emollients. Poultices made of substances retaining heat and moisture are sometimes grouped with emollients, or even regarded as emollients, but they are not rightly included under that heading. R. J. E. SCOTT.

Emotion.—In this brief discussion this term will be used as a generic word with much the same connotation as feeling when employed as an abstract noun. On the other hand, "an emotion" is a time period of psychophysical experience with very well-defined affective reactions; in the same sense "a feeling" is a mild emotion, less determinate, and with much less obvious bodily activity concerned. There are forty or fifty feelings readily called to mind, but the emotions proper are less than a dozen in the classification of James (which introspection shows to be correct). None the less in common usage feeling and emotion are essentially synonyms.

Let us first attempt to obtain a general, even if vague, outline sketch of what feeling, in its scientific meaning, is like. Every one knows the mental phase of the various feelings, and even if he did not no one could describe them to him. Careful analysis, however, does make this "immediate experience" of feeling richer with meaning, although of course the more important part of the psychology of the emotions ("affective psychology") describes the bodily aspect of this two-phased portion or aspect of our life.

The term "feeling" is for psychology a most unfor-

tunate one, because it means so many different things that scientific precision of expression is impossible unless one deliberately sets out arbitrarily to state the meanings he will give the word; indeed confusion and doubts and misunderstanding follow in the truly scholastic way. One may feel with his finger tips, may feel excited, or sleepy, or ill, or cold, or, on the other hand, he may feel sorrowful or frightened, or happy, or angry. The first five meanings of the term cited are but examples of very many complex sensational experiences to which the term is applied; the latter, feeling happy, or sorrowful, or angry, or frightened, are usages of the word which are the most exact scientifically, and these mental conditions are indeed emotions when of the requisite intensity and purity. Admiration, or piety, or disgust are feelings in the proper sense which rarely pass over into emotions. Thus much in the way of terminology, by means of examples.

We seek now to review the chief characteristics of emotion proper, feelings being for our purpose but mild and relatively simple forms of emotion; to describe the latter, or to analyze it, is therefore to represent the former as well. The emotions are feelings which are intense, temporary, and characterized, each, by a set of obvious bodily reactions. Every emotion involves a subject, the person in whom it takes place and by whom it is immediately experienced; and an object, that thing (objective or subjective, "real" or ideal) which is the occasion of the emotion at the time. Every emotion has a mental aspect, which is the complex consciousness during the emotion; and a bodily aspect, consisting of widespread and probably universal bodily movements and tendencies to movement. Every emotion has a sense of excitement (due to the liveliness of the other elements); and, finally, there may be and there may not be in an emotion a tone of pleasantness or unpleasantness. The last element, the affective tone of an emotion, is in a sense of course part of the complex mental experience of the emotion, but it is by no means always present, and forming one of the most important aspects of feeling, is not improperly mentioned as an element of emotion by itself.

Let us now briefly discuss such of these emotional components as are most important practically, namely, the mental experience, the bodily movements, and the affective tone.

The psychical side or aspect of an emotion is of course what one feels while experiencing the emotion—to describe it is as impossible as it is unnecessary, for every reader knows the experience as well as any one. The differences between an emotion of fear and the consciousness in an emotion of anger or of surprise are perfectly well marked in every memory—one is never in doubt whether he is afraid or sorrowful. To account for these differences is, however, a different matter, and to do so one must refer to the next element requiring explanation, namely, the bodily aspect of emotion.

This is what used to be called the expression of the emotion, a term no longer exact, according to the physiological theory of emotion, because this bodily phase is itself an essential part of the process; one does not think now-a-days of a feeling or emotion as merely mental experience—this is now known to be only half, one way of looking at it, one aspect, where a dual mechanism is involved. It is very unsatisfactory to attempt to describe in a little space what the bodily side of even a single emotion is like, and to convey a notion of emotional "expression" in general is out of the question, each emotion being an hereditary physiological law unto itself. But, roughly, the physical side of emotion consists of movements and of tendencies to movement ("strains") in many different parts of the body, and most probably in its every nook and corner. There are contractions of muscles more or less complete and more or less universal over and throughout the body—of the muscular fibers in the walls of the almost omnipresent arteries and everywhere in the numerous glands, as well as of the voluntary muscles of the face and limbs. There is increase or decrease in glandular activity all through the body. Since we have learned, recently, of the close mutual dependence between the autonomic nerves and the hormones especially adrenalin (spinephrin, iodothyrin, and pituitrin, this last set of bodily reactions has taken on a new interest. Professor L. F. Barker (Aug., 1913) states the present attitude adequately thus: "In how far those sudden and violent excitations of the autonomic nervous system which accompany strong emotions are due to the innervation of the glands of internal secretion, and in how far they depend on direct neural conduction from the brain, we are as yet but ill-informed. I need only remind you of the vasodilatation of the face in the blush of shame, of the stimulation of the lacrymal glands which yields the tears of sorrow, of the palpitation of the heart in joy, of the stimulation of the sudoriparores glands which precedes the sweat of anxiety, of the stimulation of the vasoconstrictors, the pupil dilators, and the pilomotors in the pallor, mydriasis, and goose-skin of fright, to illustrate some of these violent autonomic excitations. While we do not yet understand the exact mechanisms of association among the activities of the cerebrum, the endocrine glands, and the reciprocally antagonistic autonomic domains and their end-organs, we can begin to see the paths which must be followed in order that more exact knowledge may be gained."

Cerebrospinal and autonomic influences both, then, are concerned in that bodily phase of emotion. What this statement means in the complexity of bodily effects produced, one familiar with anatomy and physiology can readily understand. The total effect is perhaps nothing short of change in every organ and in every part of every tissue almost of the body, through the complete unification made possible by the nervous system. The indefinite number of combinations possible between these physiological elements explains the enormous empirical complexity of the emotional expressions and their immense variety, both in kind and in degree or intensity. These bodily changes constitute the "physical basis," so-called, of emotional phenomena.

The sense of pleasantness or unpleasantness, the affective tone of an emotion, needs a word or two of discussion, because practically it may be the dominating element of feeling, just as theoretically it may be wholly wanting in any affective experience. Into the psychology of pleasure and pain, of pleasantness and unpleasantness especially, we cannot go; and there is no need of doing so, the important fact being that usually an emotion or a feeling is either distinctly agreeable or disagreeable, and at times almost painful or pleasurable, although rarely the affective tone cannot be distinguished, because there is none. Who, for example, will say whether an average emotion of surprise or of anger is pleasant or unpleasant? In the emotion of delight, on the other hand, or of fear, the affective tone is very prominent; in the former instance very pleasant in its character, and in the latter of a nature to be easily confused with pain.

Such being a rather technical idea of emotion, let us glance again briefly at some of its more general properties. In the first place, feeling (and here emotion is included) is that sort of consciousness, that aspect of the mental process which is closest to the soul or ego of the individual. It is, one might claim, the most personal mode of consciousness, that in which the subject takes most interest. To account for this, consider its inclusion, usually of an affective tone, of a sense or experience akin to pleasure or to pain. Of all biological principles scarcely any is more universal than that every animal, be it worm or man, seeks satisfactions and avoids dissatisfactions, seeks pleasantness and shuns unpleasantness, strives after pleasure

and evades pain in all its normal inclinations. When it does not do so, the presumption is warranted that the animal, almost man, always has gotten beyond the biological into the range of satisfactions with which we here have no concern. It is, then, because affective states more than other sorts of consciousness have this tone of pleasantness, or of unpleasantness usually, that these feelings and emotions control the conduct of the individual more than do other sorts of experience. One remembers the emotion vividly that gnawed his soul, and it seems as a criterion, as the occasion or the deterrent of future action. Again, the emotions, theoretically as well as introspectively, are largely interwoven with the instincts, many of them being, one might almost say, minor instincts, more temporary as a rule, but otherwise of the same general nature, although, of course, different in particulars.

One can speak of the feelings and emotions, in an important sense, as the reactions of the individual personality at the same time to its environment and to the cenesthetic fabric of sensations (see the article on *Cenesthesia* in the preceding volume of this HANDBOOK) characteristic of the respective feeling or emotion. Feeling then is the aspect of mind (will and ideation being the other two) that is closest to the very soul, so to say, of the individual. The reason for this lies, it is clear, in the recondite nature of pleasantness and of unpleasantness, the "affective tone," characteristic of all feeling. Here (be it repeated for emphasis) is the fundamental fact of life; every sentient being seems to seek inevitably his possible maximum of satisfaction. It often is not pleasure, and sometimes is not pleasantness, but it always is, apparently, the logical limit of this kind of experience, a limit always to be expressed as satisfaction. In emotion and affective experience generally this phase of experience is most obvious and most characteristic. The therapeutic and medical and physiologic value of this general state of mind, this inevitable appetition, in the long run are quite beyond easy appreciation. But the reason lies in the universal stimulation, perhaps, which feeling of the pleasant sort produces in the organism as an uniquely delicate and sensitive "machine."

As we have noted above, a chief characteristic of emotional events is the universality of their physical influence, that is in the body. Whether consciously or not, an emotion uninhibited concerns more or less every part of the frame, thus giving the richness which is empirically characteristic of the typical emotions. The supposition explains, too, the uniquely complex "expressions," their great variety, and consequently their interest for the observer. Thus the emotions, by means of their bodily side (as in all other phases of mind), become modes of social communication of great importance, second in value only to written or vocal speech. Much care and pains are devoted to teaching the child the various proper usages of speech, while the "language of the emotions" is relegated to poetry and to sentimental relations. It is our intention only to suggest what a large, practical, even monetary, worth an acquaintance with emotional expression may sometimes have, thereby speaking a word for the worth of knowledge other than that of facts and abstract theories.

It has been already suggested that the two aspects of emotion, the mental and the bodily, are parallel to each other, more or less, and wholly and mutually dependent. The details of this correspondence (really, we may presume, an *interrelation*) are as yet vague, but the general fact seems clear and certain enough. As a consequence of this relation, one sees that bodily "expression" accompanies the mental experience; one feels an emotion, and simultaneously his body takes the attitude, or does the things, or exhibits the expression peculiar to that degree of that particular sort of emotion. For example, seeing a mad dog rushing about a street, one feels frightened, looks frightened, and runs away. On the other hand, if one artificially imitate the "expression" of an emotion (provided it be done with the requisite accuracy and vigor sufficient to raise the needful excitement in the mind), the corresponding feelings are experienced also. (James.) Thus most actors who produce truly exact imitations of nature, that is, the really great performers, thoroughly feel, almost always, the emotions they pretend to feel on the stage. Imagine Mrs. Fiske or Eleonora Duse playing one of their remarkable parts without feeling, to their soul's depths, what they make us feel. The pedagogical and therapeutic application of this principle (that, taking an attitude with the natural vigor and precision, the mental side accompanies, and *vice versa*) is common knowledge, and in the school room gets its recognition in the universal attention given erect positions, "shoulders back," "heads up," etc. This is not a matter only of proper physical development, for it directly influences beneficially the mental attitude of the pupil toward things in general, toward himself as person and as agent in particular. Gladness is expansive and extensor in its bodily expression, while sorrow and self-abasement are contracted and stooping. Joy, too, is active and progressive, strenuous (sthenic is the technical term), while grief and pain, its opposite, are quiet and obstructive of real living. Thus physical activity stimulates mental activity, more or less, when not overviolent, and develops latent mental vigor. It is important, then, to insist that the young student shall conform to the rules of bodily posture which experience has taught give the greatest physical and mental freedom. To hold one's head up, other things being equal, is, we may be sure, to hold one's moral and perhaps mental standard higher, too. This principle is basal in Medicine.

Turn this matter quite about and one also sees relations of value everywhere. Just as mental attitude accompanies physical attitude when part of an emotion, so of course bodily expression, in the technical sense, is concomitant with the mental side of affective states. Good humor means physical vigor and liveliness and useful bodily functioning; therefore good humor has a very practical value. The best educators, like the best popular lecturers, appreciate this relation and put it continually into practice. The object of the lecturer in this is to give his auditors pleasure, for which they have paid him in advance. The object of the educator should be to interest his students and so inevitably to draw their attention and secure vigorous effort to learn. Whatever gives one pleasure (ethically, satisfaction) interests above all else. In an entirely homologous, and more important way, the object of the physician should strenuously be to take advantage of the sthenic influence of pleasant emotion in every possible instance and at every possible moment when it is not contraindicated.

Once more. An emotion is a system or set of reactions which tend to occur on the presentation to the individual of the proper stimuli under the necessary subjective conditions. In the young child and in the savage, as well as in the brute in his natural state, one sees these emotional reactions very generally carried out in their theoretical form. In civilized communities among adults we observe, on the contrary, comparatively little of affective expression; in some nationalities, however, more of it than in others. The tendencies which have been at work thus to modify and mollify the natural emotions of men are various, but, however interesting to medical theory, cannot be considered here. These, however, all tend to the same end, namely, toward repression or inhibition of the bodily side of the emotional dual process, and regularly, we may suppose, at the expense also of mental affective experience. This inhibition of natural tendencies or "expressions" for the benefit of other tendencies more generally useful, is part of

civilization, a function of every phase of education. This is indeed perhaps the hardest problem and certainly the most important as one starts out to educate a child: so to interest him that he will gradually learn to inhibit extraneous and especially affective influences, so that he can devote his attention and energies to useful systems. In a similar manner it is becoming recognized as a basal therapeutic necessity in medicine to teach one's patients the resistless force of harmful influences becoming habitual, and especially when (as is usual rather than unusual) an emotional tone is involved with its persuasive tang either pleasant or unpleasant.

The educational element of his obligation to society the physician is especially prone to forget or to ignore. The very least the intelligent practitioner can do, however, on the sound principle of *noblesse oblige*, is to see to it that every patient who can benefit thereby receives from his entire environment the curative influence of a happy, or at least pleasant, emotional tone. Modern psychology and physiology are now engaged, in part, in making us really understand the scientific basis of this familiar old idea. It is not religion or Eddyism or mental healing, but an important phase of modern therapeutics, at whose foundations are the theory and facts of emotion on a strictly sound scientific basis.

Readers who care for further technical information on emotion and feeling might consult the "Principles of Psychology" by Wm. James, or the "Outlines of Psychology "by Harold Höffding. Henry Maudsley's discussion of the affective tone is unexcelled. For monographs on particular emotions see Angelo Mosso's "Fear" and the present writer's "Emotion of Joy," which last contains a bibliography of most of the available literature on this subject.

GEORGE V. N. DEARBORN.

Emphysema, Pulmonary.—Emphysema of the lungs, is the condition in which there is dilatation of the air vesicles with atrophy of the alveolar walls. Strictly speaking there come under this definition three forms of the disease: hypertrophic or large-lunged emphysema, atrophic or small-lunged emphysema, sometimes known as senile atrophy, and local or compensatory emphysema. In addition to these forms it is convenient to consider here certain other conditions to which the term emphysema is applied, viz., acute vesicular emphysema and interstitial emphysema.

I. HYPERTROPHIC EMPHYSEMA.—*Synonym:* large-lunged emphysema.

Morbid Anatomy.—The lungs are large and distended and do not collapse when the chest is opened. The borders are rounded, encroaching on the heart, sometimes meeting and even overlapping beneath the sternum; the apices project far above the clavicles and the diaphragm is depressed by the voluminous lungs. In color the organs are of a pale gray or grayish-red, and often streaked with lines and spots of pigment. The outlines of the lobules are more distinct than in health, and on close observation the individual air cells appear as clear dilated vesicles reaching the size of small shot or somewhat larger; in occasional instances large thin-walled blebs or bullæ form from the union of smaller vesicles and reach the size of a cherry or walnut. To the feel the organs are soft and downy, they pit on pressure owing to loss of elasticity, they do not crepitate like healthy lungs, and when placed in water they float higher than usual.

These changes, although they may be generalized, are seen earliest and reach their highest development in those areas of the lungs which are unsupported by firm and resisting portions of the chest wall. They are thus best seen at the apices, along the anterior borders, especially on the left side, at the lingula and at the bases of the lungs, particularly at the free borders and on the left side where the firm support of the liver is lacking.

Microscopically the alveolar walls are much thinned and the vesicles and infundibula are much enlarged. Rindfleisch has shown that extensive anastomoses take place between the pulmonary arterioles and the veins.

The bronchi often show evidence of chronic catarrhal inflammation, a condition which, as will be presently seen, is a frequent precursor of emphysema.

In rare instances rupture of the thinned-walled vesicles may occur and an escape of air take place into the pleura, producing pneumothorax, or into the cellular tissue of the lung or mediastinum, whence it may reach the subcutaneous tissues of the neck and thorax and cause subcutaneous emphysema.

Changes in the right heart are commonly seen in advanced cases of emphysema. Owing to the increased strain thrown on the right ventricle as the result of the occlusion of large areas of capillary vessels, dilatation-hypertrophy sets in primarily on this side, leading to tricuspid regurgitation and ultimately to the same train of morbid changes, consisting in chronic congestion of the various viscera, as are seen in cases of chronic heart disease. The main branches of the pulmonary artery sometimes undergo chronic sclerotic changes, the result of long-continued high arterial pressure.

Pathogenesis.—Much discussion has centered about the pathogeny of emphysema, and the chief theories of its production may be briefly discussed under three heads.

1. Inspiratory Theory.—Laënnec first advanced the view that emphysema occurred during inspiration owing to the inspiratory movements being more powerful than the expiratory. Gairdner subsequently developed this theory of emphysema and put forward a hypothesis which is still regarded as correct but only in a very limited sense. According to this writer diminution in the volume of the lung, due to collapse from bronchitis or bronchopneumonia, or again recession from fibroid change, precedes the development of emphysema, and the adjacent air vesicles dilate to take the place of the collapsed areas. That such a sequence does occur is generally admitted in the development of local or compensatory emphysema, but it is regarded as of altogether secondary importance in the production of the form of the disease now under discussion. Gairdner's suggestion that the inspired air expanded in the air vesicles under the influence of the body heat hardly needs refuting, as it is now well known that the inspired air is heated in the nasal cavities.

2. Expiratory Theory.—Jenner (Med.-Chir. Soc. Trans., vol. xi.), although preceded by Mendelssohn, independently advanced the view that emphysema was produced chiefly by forces acting during expiration. He showed that during violent expiratory actions, such as cough or straining efforts, certain portions of the lungs being unsupported by rigid parts of the chest wall, yield and dilate under the influence of expiratory forces, and that the apices, the anterior borders and the bases, especially along their free margins, are exactly those parts which are least supported and which are affected earliest and in the highest degree by emphysema. In support of his view Jenner pointed out the bulging that takes place at the apices during an attack of cough, especially when the lung is affected by emphysema, and he also quotes Louis as his authority for the statement that the base of the left lung is affected by emphysema twice as often as the right, owing to the absence of the firm support by the liver.

The frequency of emphysema in old-standing cases of bronchitis is readily explained by the application of Jenner's views. During the accompanying cough a deep inspiration is taken, the glottis is closed, and a

violent expiratory effort is brought about by the muscles of expiration, compressing the lung and causing dilatation of these organs in the parts referred to. A similar mechanism comes into play during the severe muscular efforts caused by such movements as lifting or dragging heavy weights, straining at stool, or playing on a wind-instrument.

The emphysema which is so frequently seen in old cases of asthma is not so readily explained. The bronchitis and cough which are such common accompaniments of asthma are undoubtedly responsible in great part, inducing emphysema by expiratory efforts as in bronchitis, but this hardly seems the whole explanation. During an attack of asthma a temporary emphysema frequently develops, particularly when the attack is prolonged or severe, and pases off as it subsides. The enlargement and fixation of the chest in the inspiratory posture, together with the noticeable difficulty in expiration, indicate difficulty in expelling air from the chest, and in consequence the alveoli become overfilled. Accepting the usual view that asthma is due to obstruction of the smaller tubes, resulting from spasm or catarrh, it is assumed that the resistance to the exit of air is greater than to its entry, and in consequence the alveoli gradually become distended.

3. Vital Causes.—Most clinicians agree that emphysema is occasionally found when no apparent cause has been in operation or when the history of cough or other cause has been slight or of short duration. In such instances it is assumed that there is a congenital deficiency in the quality of the lung tissue, allowing it to yield under the ordinary strain to which it is of necessity subjected. In support of this view it may be urged that emphysema is not uncommonly found in several members of a family, and a number of observers have recorded a marked hereditary tendency in the disease.

Cohnheim has endeavored to show that a defective development of elastic tissue underlies the production of emphysema, but a deficiency in this tissue may simply represent the atrophy accompanying the morbid process.

Summing up, then, the conditions tending to produce emphysema we must attribute special weight to violent expiratory efforts. Owing to the yielding character of certain portions of the thoracic cavity the air is compressed and driven into the underlying alveoli, which dilate and ultimately become emphysematous. In this form of emphysema inspiratory causes, apart from the possible inspiratory distention caused by asthma, play no part, and lastly, while it seems probable that as in other tissues there may be a lack in resisting power, we have no definite anatomical knowledge in what this consists.

Etiology.—Age. Emphysema occurs at all periods of life, but it is more frequently found in adults beyond middle life, although it occurs even in young children.

Sex. Males are more exposed to the causes favoring the development of emphysema, and it is consequently more frequent in this sex than in females.

Occupation. All occupations involving exposure and catarrhal effections or heavy straining efforts tend to produce emphysema by causing violent expiratory efforts. It is thus found more amongst the laboring than the leisure classes.

Previous Diseases. Of all the causes of emphysema chronic or recurring bronchitis is by far the most common. It is indeed unusual to find old-standing cases of this nature without some accompanying emphysema. In children the cough of pertussis and of the pulmonary lesions associated with measles are occasional factors in the development of the disease, and Osler remarks on the frequency of emphysema in the asthmatic attacks associated with adenoid growths. In chronic cardiac disease and in arterial sclerosis with its accompanying cardiac and renal lesions emphysema is often seen.

It is probable that inflammatory changes in the lung sometimes lessen its resisting power and favor the production of emphysema. A case of Hertz's is quoted by Hilton Fagge, in which emphysema rapidly developed in a cornet player after an attack of double pneumonia.

Symptoms.—The onset of emphysema is slow and insidious, although it occasionally develops rather rapidly after an attack of bronchitis or whooping cough. No special symptoms are noticed in the earlier stages of the malady, although there is a frequent history of chronic or recurring bronchitis.

Dyspnea is by far the most important and prominent feature of the malady. The patient notices after any unusual effort that he suffers somewhat from shortness of breath. The difficulty is aggravated by every slight attack of bronchial catarrh. As the disease advances the dyspnea increases and there are paroxysmal attacks like asthma, especially with any accession of catarrhal trouble, and are accompanied by wheezing, prolonged expiration, and orthopnea. Eventually dyspnea becomes more constant and present even at rest, the patient sits propped up by pillows or in an armchair, and the slightest exertion is accompanied by an increase of dyspnea.

A slight tinge of lividity about the lips and finger nails is present, indicating deficient aëration of blood, and in advanced stages there may be a most intense degree of cyanosis. With this, however, the patient may not be incapacitated for slight exertion, and as Osler remarks there is hardly any other condition in which a patient may go about and even walk to a hospital with a lividity of startling intensity.

Hemoptysis is not often noticed in emphysema, and when present is suggestive of a complicating tuberculosis. Recurring hemorrhages have, however, been observed, and although usually slight, have been known to be severe and even to prove fatal.

Cough and expectoration, strictly speaking, depend on associated bronchitis, but many individuals, in whom bronchitis is a subordinate feature, suffer from a slight cough and expectorate clear perles of mucus.

The course of the disease is usually progressive. The symptoms are much aggravated during attacks of bronchitis, and each attack tends to increase the emphysematous condition and the distress of the patient. Dilatation of the right heart may still further aggravate the dyspnea and distress of the sufferer; edema of the lower extremities, albuminuria, and signs of portal obstruction set in and the clinical picture is that of advanced cardiac disease. There is dilatation of the veins of the neck and sometimes pulsation indicating tricuspid regurgitation.

Although there is commonly some failure in general nutrition in emphysematous patients, it is only in the terminal stages of the disease that emaciation becomes at all marked. Clubbing of the finger nails is less frequent than might be anticipated, occurring, according to Esbach, only once in six cases.

Physical Signs.—The recognition of the disease rests on the presence of certain physical signs. In a well-marked instance the appearance of the chest is very characteristic. The thorax is rounded or barrel-shaped, the anteroposterior diameter is increased, and a cyrtometer tracing may even show that it exceeds the transverse. The clavicles are prominent, the supraclavicular and infraclavicular fossæ are deeper than usual, the shoulders are rounded, and the back is convex, causing the scapulæ to assume a more horizontal position. The thorax is in fact fixed in the inspiratory position, and the sternomastoid and trapezius muscles are prominent and hypertrophied. The first and second pieces of the sternum sometimes form a prominent angle, known as the angle of Ludovici, the bone being convex from above down; the intercostal spaces are wide, the subcostal angle is increased, while the projection of the lower ribs gives

the abdomen a hollow appearance. There is very slight inspiratory movement, the tape measure showing a movement often not exceeding one-quarter or one-half an inch,

The vocal fremitus is somewhat diminished as is also vocal resonance.

While the above signs are present only in well-marked cases of the disease, by means of percussion even slight degrees of emphysema can be detected. The resonant areas of lung are increased, and instead of cardiac dulness beginning at the fourth rib it is found at a lower level and may indeed be altogether replaced by pulmonary resonance which passes into the tympany of the stomach. The liver dulness is also lower than usual, and in marked instances may be completely replaced by pulmonary resonance. Although displaced downward, it is only seldom that the hepatic border can be palpated owing to the arching forward of the lower ribs already referred to. In the back the resonant note of the lungs is also lower than usual, reaching as low as the lower border of the twelfth rib. Not only are the resonant areas of the lungs increased in extent, but the character of the note is changed, becoming louder and deeper than normal, and in some instances it is even tympanitic.

On auscultation the breath sounds are distant and feeble, while expiration is frequently but by no means always prolonged.

The cardiac impulse is feeble owing to the presence of the lung between the heart and the chest wall, and both first and second sounds are often much enfeebled from the same cause. A systolic murmur is not very uncommon at the lower end of the sternum and sometimes indicates a tricuspid regurgitation. Increased pulsation in the epigastric region is often found due to the low position of the diaphragm, and it is sometimes intensified by enlargement of the right ventricle.

Diagnosis.—Emphysema is readily recognized by the characteristic shape of the chest and, in slighter degrees of the affection, by the increases in the resonant areas of percussion. A history of bronchitis should always suggest careful mapping out of the extent of pulmonary resonance. Emphysema is very apt to obscure the diagnosis of other affections within the thorax, and it may prove difficult or impossible to recognize an enlarged heart, an aneurysm, or a tuberculous focus at the apex in the presence of marked emphysema. The diminution of the liver dulness sometimes leads to an erroneous diagnosis of cirrhosis, an error easily committed without a due appreciation of the increased area of pulmonary resonance.

Prognosis.—Emphysema is an extremely chronic malady, lasting for a long period of years. The prognosis is influenced largely by the frequency and severity of attacks of bronchitis, each of which tends to cause further damage to the lung tissue. In individuals who can afford to reside in a suitable climate and avoid attacks of bronchial catarrh the condition may be stationary. The condition of the heart and kidneys requires careful consideration. The outlook is not good when evidence of breaking down of cardiac compensation is present, and such serious signs as dropsy and albuminuria usually presage a fatal issue. Emphysema is a frequent accompaniment of interstitial nephritis and is in such instances altogether a subordinate feature, the prognosis resting on the condition of the kidneys.

Treatment.—Jenner truly remarks that as "emphysema is an incurable disease, its prevention is of the highest importance, and to determine its cause . . . is to determine to some extent the means to be employed for its prevention." It is of much importance to prevent frequent recurrences of bronchitis and to this end the various causes of bronchitis should be as far as possible avoided. If circumstances permit, residence in a temperate and equable climate is to be recommended in winter and in the changeable and uncertain weather of the spring and fall. After the development of any degree of the disease it is of importance to avoid occupations involving straining efforts as such are certain to aggravate the malady.

Patients with emphysema usually seek advice for attacks of bronchitis or asthma, and as the treatment of these conditions does not differ from that ordinarily adopted it is not necessary further to refer to them here.

The use of the compressed-air bath is highly spoken of by C. T. Williams, Fowler, and others. Dyspnea is markedly lessened and the good effect continues after a course of baths. The lack of apparatus has hitherto prevented any extensive use of this mode of treatment. Expiration into rarefied air, carried out with the view of emptying the chest of residual air and so aiding expiration, has not been attended with such good results as the use of compressed air.

When symptoms of cardiac failure are present digitalis and strychnine are of value, and in cases of marked cyanosis and dyspnea bleeding and the withdrawal of ten to twenty ounces of blood may be necessary.

It is of importance not to overload the stomach, as distention of the abdomen increases the difficulty of breathing and precipitates asthmatic attacks. An occasional dose of calomel or blue pill followed by a saline is of much value in relieving the portal circulation, particularly in plethoric subjects.

II. Atrophic Emphysema.—*Synonyms:* Small-lunged emphysema, Senile atrophy. This variety of emphysema is met with in old people and is really a senile atrophy of the lung, accompanied by some dilatation of the air vesicles.

The contrast between hypertrophic and atrophic emphysema is very striking, the only feature they have in common being some dilatation of the air sacs.

In atrophic emphysema the lungs are small and dark-colored from excess of pigmentary deposit. They can be compressed into a very small space and collapse when the thorax is opened. The bronchi share in the general atrophy and sometimes present evidences of catarrhal inflammation. Some of the air cells are enlarged, partly as the result of atrophy of adjacent alveolar walls, partly from the bronchial cough which is so common in advanced life. The other organs present the changes of senile involution.

Individuals who are the subjects of this condition are thin, old, and shrivelled-looking, and they do not suffer from any symptom which can be dissociated from the debility and failure of old age. Dyspnea is absent owing to the general atrophy of the tissues causing a lessened demand for oxygen.

The thorax is diminished in size and the ribs lie more obliquely than usual, being closely packed together and the lower ones depressed so as to be near the iliac crest. The shoulders are often rounded and stooping is therefore present. The percussion note is often hyperresonant, owing to the thin chest wall, but the pulmonary area is not increased as in the hypertrophic form. Cardiac dulness is not diminished and may even be increased owing to retraction of the lungs.

III. Compensatory Emphysema.—This form of emphysema results from disease of any portion of the lung in which the volume of the organ is diminished. It is seen constantly in the neighborhood of old tuberculous foci or of areas of collapse in bronchopneumonia. With disease resulting in contraction of one lung the opposite side becomes emphysematous, this change being seen in its highest degree in the fibroid lung, and to a lesser extent in pleurisy or pneumothorax. In the earlier stages of the affection the air vesicles are simply dilated, but ultimately the adjacent alveolar walls atrophy and a permanent dilatation ensues. Gairdner's view that emphysema is due to inspiratory stretching of the air vesicles is probably in part the explanation of this form of emphysema,

although the expiratory stretching due to cough, so rarely absent in pulmonary disease, doubtless intensifies the condition. When confined to a small area this form of emphysema is chiefly of pathological interest and may give rise to no physical signs. A hyperresonant note with feeble respiratory murmur and prolonged expiration over a limited area of lung is suggestive of the condition, and if present at the apex of a lung usually indicates a tuberculous focus.

Compensatory change in a healthy lung may be of the nature of true hypertrophy. It is indicated by an increased rather than diminished expansion, and by the presence of puerile breathing.

Acute Vesicular Emphysema.—In any condition in which extreme dyspnea is present this type of emphysema develops. It occurs in the dyspnea of cardiac or renal disease, in asthma and bronchitis, and in obstruction of the air passages.

There is only a temporary distention of the air vesicles, passing off with the cessation of the dyspneic attack, and not going on to atrophy and destruction of the alveolar walls.

The condition is recognized by the extreme inspiratory distention of the thorax, by the increase of the resonant areas of the lungs, and by the hyperresonant note. Edema is frequently present, evidenced by the crackling râles at the bases and by sonorous and sibilant râles over the chest.

The *treatment* is that of the primary condition.

Interstitial Emphysema.—This form of emphysema is rather rare and, clinically, is of but slight importance.

Air occasionally passes into the interstitial tissue of the lung from rupture of an air vesicle. This accident is seen after severe paroxysms of cough, and it is probable that such a condition not infrequently occurs and recovery ensues without any special symptoms. In some instances, however, the air passes along the connective tissue to the mediastinum and thence to the subcutaneous tissue of the neck and thorax, where it is recognized by the crepitating sensation conveyed to the fingers. On the other hand, the air may find its way down from a wound in the neck, beneath the deep fascia, and thence to the connective tissue of the lung. Money has recorded cases of tracheotomy wounds in which this complication arose, and in a few instances pneumothorax was induced by rupture of the pleura.

Frederick G. Finley.

Emphysema, Subcutaneous.—By this term, or pneumatosis, is meant the presence of air or other gaseous compounds beneath the skin.

Symptoms.—The evidences of this condition are: a swelling covered with skin of either normal appearance or, if the pressure upon it be great, rather pale; this tumor pits upon pressure, as in the case of anasarca, but the pitting more quickly disappears when the swelling is due to the presence of air. Palpation causes a peculiar crackling or crepitation in the subcutaneous tissues. If the air have entered from without, a wound or puncture can generally be discovered; if from within, expiratory efforts with closed lips and nostrils will generally produce immediate increase in size. It is possible for the whole subcutaneous tissue to become inflated from any superficial part of the body as a starting-point.

In case the emphysema is that of decomposition, there may be an altered hue of the integument; but the discoloration, of course, is entirely independent of the emphysema.

Etiology.—Subcutaneous emphysema may result from causes either traumatic or pathological. Among instances of the latter may be mentioned ulcers or abscesses communicating with the air passages, and, as already suggested, gangrene. We may include in the discussion of this subject emphysema of other parts external to the lungs, such as mediastinal and submucous collections of air.

In the *head*, orbital emphysema sometimes follows a blow of sufficient violence to break one of the thin and fragile bones of the inner wall of the orbit—the lacrymal or the orbital plate of the ethmoid. If, soon thereafter, the patient blows his nose, the compressed air finds a ready exit from the nose into the orbit, and distends the lids.

Eustachian Emphysema.—An ulcer of the tube, or a rupture following awkward Eustachian catheterization, may lead to distention and approximation of the pharyngeal walls by the dissecting air. Blowing the nose and the Valsalvan experiment increase the emphysema in these cases. Von Tröltsch mentions a case in which dysphagia consequent upon such emphysema persisted for five days.

In the *neck* we may have escape of air as a result of foreign bodies, ulcers, or abscesses perforating the esophageal, laryngeal, or tracheal wall; but emphysema will not be produced if, as a result of the perforation, a broncho-esophageal fistula is established.

Ulcers of the larynx or trachea may lead to submucous dissection by air. Wounds of the neck penetrating these parts may be followed by subcutaneous emphysema if there is not free escape for the expired air. Under these circumstances inflation of the skin has been known to occur over an area extending from the head to the scrotum. As a rule, the consequences are not serious; but Holmes quotes Hilton as stating that emphysema about the phrenic nerves may so interfere with their functional integrity as to cause death.

During tracheotomy, and afterward if much inspiratory difficulty is present, Champneys finds that anterior mediastinal emphysema and even pneumothorax are liable to occur; and this is especially so if artificial respiration by Schultze's method is employed.

In the *chest* we may have the surgical symptom in question produced in several ways: Pathologically by the opening of a vomica or abscess of the lung into the parietes of the chest, the two pleural surfaces being adherent at the point where the abscess perforates. Emphysema sometimes complicates wounds of the chest-wall, both the penetrating and the non-penetrating varieties. In the latter instance, the air which enters the wound from without during one movement of respiration is prevented in a valvular way from escaping during the opposed movement, and is disseminated by the muscular and tegumentary pressure upon it during this movement. In the case of wounds penetrating the parietal pleura only, we may, besides the consequent pneumothorax, have a subcutaneous emphysema from the same cause.

Wounds that penetrate the lung, and a puncture of the lung by a fractured rib, are alike liable to produce emphysema, air escaping from the lung with the same result as in the case last given.

A rare variety of traumatic emphysema of thoracic origin is that consequent upon rupture of air cells by violent expiratory efforts, with a closed or partially closed glottis, as while coughing, straining, or blowing a wind instrument. Here the air makes its way between the lobules, and, unless it ruptures the pleura, producing pneumothorax, it escapes at the root of the lung into the mediastina, and thence into the cellular tissue of the neck, becoming subcutaneous. Guttman says: "Most of the cases of this variety of emphysema are observed in connection with croup, diphtheritis of the larynx, whooping-cough, and bronchitis in children, and with advanced pulmonary emphysema in the aged." I have seen one case complicating whooping-cough. The patient, a child of two years, had been suffering for about three weeks, the parents said, from violent fits of coughing.

I was called to treat the sudden appearance of "dropsy" in the case. I found the skin of the head, neck, and chest distended, crepitation everywhere well marked, and no dropsy. Whenever the child coughed the swelling increased in size suddenly, apparently causing distention first in the left supraclavicular region. The respiration was rapid, but seemingly free; the pulse rapid and feeble. The child died within a few hours. Unfortunately, no autopsy was allowed.

In the *abdomen* we may have subcutaneous emphysema from ulcerative perforation of the stomach or intestine at a point previously adherent to the abdominal wall. Unless such adhesions prevent it, gas will escape from the viscera into the peritoneal cavity.

Artificial Production.—Subcutaneous emphysema possesses an interest for us outside of its pathological or accidental causation. It has often been induced intentionally by the malingerer; and, moreover, its production was once seriously advocated by Dr. H. R. Sylvester in an article entitled "On Life-saving from Drowning, by Self-inflation." Here it was recommended that those in peril of the deep should make a small puncture or cut in the cheek, leading from the mucous membrane about opposite the first molar tooth to—but not through—the superficial fascia and skin; and then, closing the lips tightly, they should proceed to blow themselves up, until the skin of the head, neck, and chest was distended. Dr. Sylvester alleged that a moderate and quite painless and harmless inflation was ample to keep one afloat without effort. It seems probable that Vidocq refers to such a practice when, in his memoirs—as mentioned by Gavin—he asserts that he could make his head swell like a bushel, without giving pain, and that he could remove all traces of it by the day following.

In order to test the degree of pain, and the subjective effects of such distention upon the skin, I some time ago performed the following experiment, assisted by my friend Dr. F. A. Manning: Having connected, by a piece of rubber tubing, a hypodermic needle with my compressed-air receiver, I forced air beneath the skin of my left forearm until the limb was much increased in size, the skin tense, and emphysematous crepitation could be felt from wrist to armpit. The pain was very trifling in amount. The distended skin was somewhat anesthetic; whereas before the injection I could distinguish separate points on the anterior surface at an average distance of four millimeters, immediately thereafter I could name them only when they were ten to fifteen millimeters apart. Still, pinching and pricking were distinctly painful. The emphysema thus induced was slow in disappearing. It was still somewhat noticeable on the third day after the experiment.

As regards the production of emphysema upon the human subject with intent to deceive, it has been employed to simulate hernia, hydrocele, hydrocephalus, ascites, etc. Gavin says: "It is a trick used every day by butchers, and has been known from time immemorial by the Ethiopians and mendicants of Abyssinia." Beck quotes Sauvage's "Nosology" regarding a mendicant who "gave his child all the appearances of hydrocephalus by blowing air under the tegument of the head near the vertex." He also cites a case of emphysema of the abdominal parietes, induced by a woman who wished to feign dropsy.

Sir George Ballingall declared that the artificial production of this for the simulation of other diseases was at one time regulated by a recipe current in the British army. The differential diagnosis of the tumors so caused presents no difficulty.

Treatment.—As a rule, air beneath the skin is of slight consequence and requires no treatment, becoming absorbed after a time. If, however, important parts—as the phrenic nerves, or the larynx, trachea, etc.—are subjected to a degree of pressure injurious to respiration, or if the subcutaneous air is spreading further and further, we may employ pressure at the point of escape, or may make incisions through the skin to give relief to tension, or both.

Robert H. M. Dawbarn.

Emplastra.—Plasters consist of mixtures of various solids which are friable when cold but are rendered adhesive by the heat of the body. The plaster masses are spread as thinly as possible upon rubber, calico, or other suitable material. Plasters may be used as a protective, to aid in the approximation of the edges of a wound, and also to keep some medicinal preparation in intimate contact with the skin. There are seven emplastra official in the United States Pharmacopœia, twelve in the British Pharmacopœia, and thirteen in the National Formulary.

		Composition.
Emplastrum Adhæsivum (Adhesive plaster.)	U. S. P.	Rubber 20, petrolatum 20, and lead plaster 960.
Emplastrum Ammoniaci. (Ammoniac plaster.)	N. F.	Ammoniac 100, diluted acetic acid 140.
Emplastrum Ammoniaci cum Hydrargyro (Ammoniacum and Mercury plaster.)	B. P.	Ammoniac 328, mercury 82, olive oil 3.5, and sublimed sulphur 0.5.
Emplastrum Ammoniaci cum Hydrargyro. (Ammoniac plaster with mercury.)	N. F.	Ammoniac 720, mercury 180, oleate of mercury 8, diluted acetic acid 1000, lead plaster.
Emplastrum Aromaticum. (Aromatic plaster or spice plaster.)	N. F.	Cloves 10, cinnamon 10, ginger 10, capsicum 5, camphor 5, cotton seed oil 35, lead plaster 25.
Emplastrum Arnicæ. (Arnica plaster.)	N. F.	Extract of arnica root 330, resin plaster 670.
Emplastrum Asafœtidæ. (Asafetida plaster.)	N. F.	Asafetida 35, lead plaster 35, galbanum 15, yellow wax 15, alcohol 120.
Emplastrum Belladonnæ. (Belladonna plaster.)	U. S. P.	Extract of belladonna leaves 300, adhesive plaster 700.
Emplastrum Belladonnæ. (Belladonna plaster.)	B. P.	Liquid extract of belladonna 100, resin plaster 125.
Emplastrum Calefaciens. (Warming plaster.)	B. P.	Cantharides 100, yellow beeswax 100, resin 100, resin plaster 1300, soap plaster 800, distilled water 500.
Emplastrum Cantharidis. (Cantharides plaster.)	B. P.	Cantharides 35, yellow beeswax 20, lard 20, resin 20, soap plaster 5.
Emplastrum Capsici. (Capsicum plaster.)	U. S. P.	Oleoresin of capsicum 0.25, adhesive plaster. 15 cm. sq.
Emplastrum Ferri. (Iron plaster.)	N. F.	Ferric hydroxide 90, olive oil 50, burgundy pitch 140, lead plaster 720.
Emplastrum Fuscum Camphoratum. (Camphorated brown plaster, or Camphorated mother plaster.)	N. F.	Red oxide of lead 30, olive oil 60, yellow wax 15, camphor 1.
Emplastrum Galbani. (Galbanum plaster.)	N. F.	Galbanum 16, turpentine 2, burgundy pitch 6, lead plaster 76.
Emplastrum Hydrargyri. (Mercurial plaster.)	U. S. P.	Mercury 30, oleate of mercury 1, hydrous wool-fat 10, lead plaster 59.
Emplastrum Hydrargyri. (Mercurial plaster.)	B. P.	Mercury 30, olive oil 3.5, sublimed sulphur 0.5, lead plaster 164.
Emplastrum Menthol. (Menthol plaster.)	B. P.	Menthol 30, yellow beeswax, 20, resin 150.
Emplastrum Opii. (Opium plaster.)	U. S. P.	Extract of opium 6, water 8 adhesive plaster 90.
Emplastrum Opii. (Opium plaster.)	B. P.	Opium 10, resin plaster 90.

		Composition.
Emplastrum Picis. (Pitch plaster.)	B. P.	Burgundy pitch 520, frankincense 260, resin 90, yellow beeswax 90, olive oil 40, distilled water 40.
Emplastrum Picis Liquidæ Compositum. (Compound tar plaster)	N. F.	Resin 5, tar 4, podophyllum 1, phytolacca root 1, sanguinaria 1.
Emplastrum Picis Burgundicæ. (Burgundy pitch plaster.)	N. F.	Burgundy pitch 300, olive oil 50, yellow wax 150.
Emplastrum Picis Canadensis. (Canada pitch plaster.)	N. F.	Canada pitch 90, yellow wax 10.
Emplastrum Picis Cantharidatum. (Cantharidal pitch plaster, or warming plaster.)	N. F.	Cantharides cerate 80, burgundy pitch. 20.
Emplastrum Plumbi. (Lead plaster.)	U. S. P.	Soap 100, lead acetate 60, water.
Emplastrum Plumbi. (Lead plaster.)	B. P.	Lead oxide 400, olive oil 800, distilled water 400.
Emplastrum Plumbi Iodidi. (Lead iodide plaster.)	B. P.	Lead iodide 50, lead plaster 400, resin 50.
Emplastrum Resinæ. (Resin plaster.)	B. P.	Resin 100, lead plaster 800, hard soap 50.
Emplastrum Resinæ. (Resin plaster.)	N. F.	Resin 140, lead plaster 800, yellow wax 60.
Emplastrum Saponis. (Soap plaster.)	U. S. P.	Soap 10, lead plaster 90, water.
Emplastrum Saponis. (Soap plaster.)	B. P.	Hard soap 150, lead plaster 900, resin 25.

R. J. E. Scott.

Empyema.—See *Pleurisy.*

Ems.—This well-known spa, about seventy miles from Cologne viâ Coblenz, is beautifully situated in the narrow valley of the River Lahn, at an elevation of 300 feet. On both sides of the river rise precipitous and forest-covered mountains. It exhibits all the characteristics of a spa town; numerous hotels, large and small, villas and lodging houses; the bath-houses with a magnificent Kursaal; public gardens admirably laid out, with a fine covered walk; bazaars, restaurants, cafés, and an English church.

The climate is a mild one, the average temperature of the year being 49.1° F., and for the summer, May, 57.9° F., June 64.6° F., July 66.2° F., August 63.5° F., September 57.9° F. The annual rainfall is 26.2 inches. The season extends from May 1 to September 30. May and September are the pleasantest months; the summer is said to be rather too warm for comfort. The town contains about 8,000 inhabitants and about 22,400 persons visit it annually, among whom are many Americans, English, and Russians. Here one can lead a pleasant life with good music and good society. For many years the Emperor William I. was accustomed to take these waters, and it was here, on July 15, 1870, that he made his memorable answer to the French ambassador which led to the war of 1870–71.

The warm waters of Ems have been known and used since the fourteenth century or even earlier, and flow from warm alkaline saline springs whose source is from a very compact sandstone which runs into quartzite; the temperature ranges from 80° F. to 120° F. The principal constituents are sodium carbonate, sodium chloride, and free carbonic acid; the Eisenquelle contains only carbonate of iron. There are eight or nine springs, all similar chemically but differing in temperature; those most used are the following, with their temperatures: Kesselbrunnen, 116° F.; Krähnchen 96° F.; Fürstenbrunnen, 103° F.; Augusta, 102° F.; Victoria, 81° F.; Kaiserbrunnen, 83° F.

According to Buckland, the chief ingredients in sixteen ounces are as follows:

Bicarbonate of sodium	14 to 15 grains.
Chloride of sodium	7 grains.
Bicarbonate of calcium	1 to 2 grains.
Bicarbonate of magnesium	1 to 2 grains.
Carbonic acid gas	6 to 8 cu. in.

These waters are used principally for drinking, but they are also employed for the purposes of gargling, inhalation, and bathing.

The baths are well fitted up with apparatus for hot and cold douches and various other methods for water application. There are six public bath-houses with 180 bath-rooms. One of the special features in the utilization of these waters is the method of applying sprays to the throat, and the inhalation of finely pulverized water, either simple or medicated. There are also rooms for gargling; a milk and whey cure; and a "terrain kur." Massage is also given in connection with the baths. The waters are chiefly drunk between six and eight in the morning, and the "jour médical" is very much like that at other European spas.

A large quantity of this water is annually exported, three and one-half million bottles. From the town a wire-rope railway leads to the top of the wooded Malberg, 1,090 feet high, where are charming walks provided with convenient resting places; there are also numerous other attractive excursions in the vicinity. The accommodations are good and abundant, and the health reports are satisfactory.

The waters of Ems are employed in a variety of maladies, and, as is more or less the case in all carefully regulated spas, the hygienic-dietetic rules inculcated along with the use of the waters undoubtedly greatly increase their efficacy. Two-thirds of the patients who visit Ems are sufferers, it is said, from chronic catarrh of the nose, larynx, pharynx, and bronchi. Indeed, one of the unpleasant features of the place is the coughing and expectoration met with on all sides. Chronic bronchitis from measles or whooping-cough receives marked benefit from the treatment here. Chronic gastric and intestinal catarrh, hepatic congestions, atonic dyspepsia associated with anemia, cystitis, gouty and rheumatic affections, especially the former; excessive nervous irritability, hypochondria, hysteria, paralytic affections of the limbs, are diseases which are treated more or less successfully at Ems. Skin diseases and scrofula are also in evidence here as at almost every other bath resort. The baths are extensively employed in cases of leucorrhea, in catarrhal conditions of the uterus and cervix uteri, in nervous cases of dysmenorrhea, and in sterility.

Indeed, one sometimes wonders what chronic diseases that flesh is heir to are not benefited at such popular spas as Ems, according to the advocates of natural hydrotherapy. The comparative ease of access from Paris or England renders Ems very available for Americans; and its attractive situation in the vicinity of the Rhine invites the weary traveller to settle down there for a brief season, improve his metabolism by a course of water-drinking, diet, and rest, and then go on his way rejoicing in his renewed health and vigor. Edward O. Otis.

Emulsa.—An emulsion (*emulsum*) is a fluid mixture consisting of a fatty body diffused in a state of fine mechanical subdivision through a more or less viscid watery menstruum. Milk is a natural example of an emulsion. Emulsions constitute a serviceable form in which to administer fixed oils whose dose is considerable—such as castor oil and cod-liver oil—for the double reason that, in such condition, the oil is less apt to nauseate, and also permits of having its taste quite perfectly disguised. The agents most commonly used to emulsify fixed oils are gum arabic and yolk of egg. Of these emulsifiers gum arabic is

the more generally serviceable; emulsions made with egg yolk being not so ready to form, and also, after making, being more prone to spoil. Gum tragacanth also may be used, but gives inferior results; and alkaline solutions, often quoted as emulsifiers, work with oils a chemical change—saponification—instead of the purely mechanical subdivision properly understood as emulsification. To emulsify with gum arabic, a thick mucilage is first made with a quantity of the gum equal to one-half the weight of the quantity of oil to be emulsified, and to this mucilage the oil is gradually added with thorough trituration, one portion of oil not being added until the previous one has been fully emulsified. After emulsification the product may be diluted with an aqueous menstruum, in quantity up to from eight to ten times the volume of oil represented in the emulsion. When yolk of egg is to be used, it should be taken in the proportion of one yolk to each fluid ounce of oil. *Volatile* oils in considerable quantity are best emulsified by first mixing with two or three volumes of a bland fixed oil, and then emulsifying the mixture as in the case of a simple fixed oil. Mixtures of *resins* and of *balsams* in fine mechanical subdivision in viscid menstrua are also sometimes called emulsions. Such emulsions may be procured by the use of the same emulsifiers and method as above described. *Gum resins* may be emulsified by trituration with water alone, the gum of the gum resin serving to make the necessary mucilage for emulsification. Six emulsions are official in the United States Pharmacopœia; the British Pharmacopœia contains none; the National Formulary includes ten.

		Composition.
Emulsum Ammoniaci. (Emulsion of ammoniac; Mistura ammoniaci.)	N. F.	Ammoniac 40, water.
Emulsum Amygdalæ. (Emulsion of almond.)	U. S. P.	Sweet almond 60, acacia 10, sugar 30, water.
Emulsum Asafœtidæ (Emulsion of asafetida.)	U. S. P.	Asafetida 40, water.
Emulsum Chloroformi (Emulsion of chloroform.)	U. S. P.	Chloroform 40, expressed oil of almond 60, tragacanth 10, water.
Emulsum Olei Morrhuæ. (Emulsion of cod liver oil.)	U. S. P.	Cod-liver oil 500, acacia 125, syrup 100, oil of gaultheria 4, water.
Emulsum Olei Morrhuæ cum Calcii et Sodii Phosphatibus. (Emulsion of cod-liver oil with calcium and sodium phosphates.	N. F.	Cod-liver oil 464, acacia 116, calcium phosphate 17.5, sodium phosphate 17.5, syrup of tolu 100, flavoring, and water.
Emulsum Olei Morrhuæ cum Calcii Lactophosphate. (Emulsion of cod-liver oil with calcium lactophosphate.)	N. F.	Cod-liver oil 464, acacia 116, calcium lactate 35, phosphoric acid 20, syrup of tolu 100, flavoring, and water.
Emulsum Olei Morrhuæ cum Calcii Phosphate. (Emulsion of cod-liver oil with calcium phosphate.	N. F.	Cod-liver oil 464, acacia 116, calcium phosphate 35, syrup of tolu 100, flavoring, and water.
Emulsum Olei Morrhuæ cum Extracto Malti (Emulsion of cod-liver oil with extract of malt.)	N. F.	Cod-liver oil 500, mucilage of dextrin 125, extract of malt 375.
Emulsum Olei Morrhuæ cum Hypophosphitibus (Emulsion of cod-liver oil with hypophosphites.)	U. S. P.	Cod-liver oil 500, acacia 125, calcium hypophosphite 10, potassium hypophosphite 5, sodium hypophosphite 5, syrup 100, oil of gaultheria 4, water.
Emulsum Olei Morrhuæ cum Pruno Virginiana (Emulsion of cod-liver oil with wild cherry.)	N. F.	Cod-liver oil 464, acacia 116, fluid extract of wild cherry 65, syrup of tolu 100, flavoring, and water.
Emulsum Olei Ricini. (Emulsion of castor oil.)	N. F.	Castor oil 32, acacia 8, tincture of vanilla 2.5, syrup 20, water.
Emulsum Olei Terebinthinæ. (Emulsion of oil of turpentine.)	U. S. P.	Rectified oil of turpentine 15, expressed oil of almond 5, syrup 25, acacia 15, water.
Emulsum Olei Terebinthinæ Fortior. (Stronger emulsion of oil of turpentine; or Forbes' emulsion of oil of turpentine.)	N. F.	Oil of turpentine 50, acacia 2.5, water 50.
Emulsum Petrolei. (Emulsion of petroleum.)	N. F.	Petrolatum album 50, expressed oil of almond 250, acacia 50, tragacanth 25, syrup 100, tincture of lemon peel 15, water.
Emulsum Phosphaticum. (Phosphatic emulsion; or Mistura Phosphatica.)	N. F.	Cod-liver oil 250, glyceryte of yolk of egg 165, diluted phosphoric acid 50, oil of bitter almond 1.5, Jamaica rum 250, orange flower water.

Edward Curtis.
R. J. E. Scott.

Emulsin is an enzyme characterized by an ability to decompose amygdalin, a glucoside. Both are found in bitter almonds and in the kernels of a number of fruits such as apple, cherry, prune, plum, and apricot. When bitter almonds are macerated in water the action of emulsin upon amygdalin gives rise to the formation of hydrocyanic acid, dextrose and benzaldehyde, according to the following reaction:

$$C_{20}H_{27}NO_{11} + 2H_2O = 2C_6H_{12}O_6 + HCN + C_7H_6O$$

Dextrose — Hydrocyanic Acid — Benzaldehyde

Frank P. Underhill.

Encephalin.—See *Cerebrosides*.

Encephalitis.—Definition.—Encephalitis may be defined as inflammation of the encephalon or brain. It is a term which has been used so freely for entirely obscure conditions that the census statistics of the United States cannot be trusted even as to the most general facts concerning the distribution of the disease. Modern work has, however, tended to limit the term "encephalitis" to inflammatory conditions of an exudative nature. Encephalitis should be used in such a way as to exclude the immediate or reparative effects of trauma, of vascular plugging and of toxic degenerations (for example, degenerations due to alcohol or lead poisoning). The conditions just enumerated are all examples of encephalopathy, but encephalitis is that separate species of encephalopathy which is due, for example, to the *Staphyloccocus pyogenes aureus*, the influenza bacillus, or the organism of poliomyelitis. The present article will accordingly exclude the various encephalopathies above mentioned from consideration. We shall likewise exclude several conditions of true encephalitis which will be considered elsewhere. For example, true encephalitis or exudative inflammation of the brain which occurs with practical constancy in tuberculous meningitis as well as in rabies, syphilitic meningitis, sleeping sickness and general paresis.

Etiology.—The etiology of (*a*) *influenzal encephalitis* and of (*b*) *pyogenic encephalitis* has been well established. The etiology of (*c*) *acute hemorrhagic encephalitis, Strümpell type,* has not been well established although the disease is clinically well defined. It may be safely stated that some forms of the Strümpell type are of pyogenic origin, some forms of influenzal origin, and some very probably are due to the virus

of poliomyelitis. There are two other forms of encephalitis which are not only etiologically but also clinically obscure, although they must be mentioned (*d*) *acute non-suppurative encephalitis. Hayem type*, and (*e*) *encephalitis neonatorum.* There is in the literature a small group of other etiologically well-characterized types of encephalitis, viz., (*f*) that due to *Bacillus typhosus*, (*g*) that due to *Bacillus anthracis*, and (*h*) that due to the *Trichinella spiralis.* Cases of different etiology cannot be safely distinguished on clinical grounds alone in the majority of cases, Experience indicates that the first duty of the clinician is to find out whether or not the case is due to the influenza bacillus. This bacillus was cultivated by Nauwerck from a case of encephalitis in 1893–94, which isolation must be considered to be the first instance of the assignation of the definite etiology to a case of encephalitic type. The encephalitis of influenzal origin is not, as a rule, a portion of the typical influenzal attack, but it follows recovery or partial recovery from such an attack after an interval of several weeks. The onset in these cases is sometimes acute, but often passes by insensible gradations through the symptoms which are persisting in convalescents from the ordinary attack of influenza. Many patients are now thought to recover from this influenzal type.

The pyogenic type of encephalitis is often no more nor less than an example of local small pyemic abscesses visible in the coarse brain as simply small "flea-bite like" hemorrhages which turn out microscopically to show a core of pus cells with a focus of organisms (for example the *Staphylococcus pyogenes aureus*). The coalescence of these small hemorrhages may give rise to the picture of "acute red softening" (this must be distinguished from the acute red softening due to bland or malignant embolism). This form is not infrequently a sequela of scarlet fever and other exanthems. It has been suggested that the origin of some of the cases of acute hemorrhagic encephalitis is an acute inflammatory lesion of the arachnoidal villi of the longitudinal sinus.

Little is known about the *Hayem* or *hyperplastic type* of acute non-suppurative encephalitis, except that such phenomena are the invariable concomitants of all not too severe destructive injuries in the central nervous system. This type of disease is still a matter of the pathological laboratories.

More important is, beyond question, the encephalitis of the new-born which was, as described by Virchow, a cause of death in a considerable proportion of still-born and new-born infants. These cases were apparently related to a great epidemic of smallpox which raged in Berlin in 1865. The question is still unsettled, since the fat-laden cells upon which Virchow grounded his diagnosis have been asserted to occur in all brains in the new-born dying of different causes. Probably it would be unsafe to base a diagnosis upon such fat-laden cells unless injury of nerve fibers could also be demonstrated. This condition also is still a matter rather of the pathological laboratory than of the clinic.

The so-called *hemorrhagic superior polioencephalitis* (Wernicke's disease).—This disease, described by Gayet in 1875, but commonly named after Wernicke, appears to be, in the vast majority of cases, a peculiar and unusual phenomenon in alcoholics. It has been recently shown that this disease, although a fairly definite clinical and anatomical entity, is actually not a true encephalitis in the exudative sense. It is unlikely that organisms will be demonstrated in connection with this disease if we trust the careful working-out of its histology by Schröder. The disease may be briefly defined as an acute hemorrhagic disease of the nuclei of the eye muscle nerves, leading to death in from ten to fourteen days, and characterized by paralysis of the eye muscles of rapid onset which quickly progresses to an almost complete ophthalmoplegia (sphincter iridis and levator palpebrarum excepted). Somnolence is a striking feature.

The disease somewhat resembles in general features Korsakow's polyneuritic psychosis, and subjects having the symptom-complex are often brought to the hospital as cases of delirium tremens. The victims are, as a rule, males of middle age who have been suffering from chronic whiskey drinking for months or years. Brain tumor and more especially apoplexy and focal encephalomalacia are sometimes suggested by the clinical condition.

Clinical Picture of Encephalitis.—Prof. W. P. Lucas and I have constructed a typical history of the onset and course of a case of acute encephalitis in a child. This description will perhaps lead to a better understanding of the disease than a catalogue of symptoms: A child of five or six years while walking along the street suddenly falls dazed for no apparent reason. In falling he strikes his head but inflicts no injury. He is picked up and carried still dazed into the nearest house. There he has one or two convulsions that involve the right side more than the left. In an hour he has apparently regained consciousness sufficiently to inquire his whereabouts. He seems dull, speaks in a far-away manner, and on questioning him as to what has happened he is unable to answer coherently but begs to go home. On reaching home in the same semi-conscious condition he is put to bed and passes a very restless disturbed night. He seems feverish and ever more listless and stupid than immediately following the initial attack. He complains of feeling nauseated, and on attempting to have him take a glass of milk, he vomits profusely. Following this he has another convulsion, and it is then noticed for the first time that his right eye is turned in. There is slight facial paralysis on this side as well as marked weakness of the right arm, but there is also some involvement of the left side, shown in the apparent hypersensitiveness of that side and of both lower extremities. His deep reflexes are variable, but on the whole exaggerated. Pupils are equal but sluggish to light reaction. Knee-jerks are very lively. Kernig is present at times, absent at other examinations. His temperature ranges from 100° to 105°, his pulse is rapid and respirations moderately so. This general condition continues for a week or ten days, during which time he has from one to three convulsions a day. He is very sensitive to touch or sound, complaining loudly of pain on being examined, and crying out that his head ached if there was any excessive noise in his room. Toward the end of this time his temperature begins to drop and the convulsions are of a less severe type and of shorter duration. In two weeks he shows evidence of wanting to sit up, is markedly less stupid. There still remains a general muscular weakness, more noticeable on the right, and the paralysis of the external rectus still persists. If left alone, however, he spends most of the day in dozing and, if wakened suddenly, has noticeable general muscular twitchings. His appetite increases rapidly and at the end of three weeks he is up and about, apparently normal except for (*a*) ocular paralysis, (*b*) defective memory, (*c*) at times defective impressibility (familiar objects not recognized), (*d*) will disorder ("has to be coaxed" to do things), (*e*) confusion or bewilderment under conditions of excitement.

The influenzal, pyogenic and Strümpell types of encephalitis are, so far as we yet know, somewhat similar, and they can hardly be differentiated at present without careful laboratory tests. Some points in connection with the influenzal type were mentioned above. In general it may be said that the influenzal type is more likely to be an occasional instance in an endemic or pandemic of influenza. The pyogenic type is more likely to be found as a sequela of one of the exanthems, especially scarlet fever. Many are coming to believe that the Strümpell type is really nothing

more or less than a special localized disease due to the virus of poliomyelitis, and a family investigated by the clinician, W. Pasteur, is often quoted in which different members of the family showed symptoms of poliomyelitis and symptoms of encephalitis.

The obscurity of the clinical picture is such that when Prof. Lucas and the writer were engaged in working out the clinical features of the disease, we had to search the records of a children's hospital not only for cases diagnosticated encephalitis, but for those diagnosticated meningitis with a question mark. The cases in children's clinics are often cases in which an effort to establish tuberculous meningitis or syphilitic meningitis has failed, both clinically and by the results of blood and cerebrospinal fluid examinations. There is a moderate leucocytosis varying from ten to thirty-three thousand. The fluid withdrawn by lumbar puncture is usually under slight pressure but excessive amounts are not as a rule found. The fluid is clear and rarely demonstrates a clot even on standing. It would seem as if the poliomyelitic cases should show often mononuclear cells. As a matter of fact, such cells, as a rule, in comparatively small numbers—from 20 to 180 cells to the cubic millimeter—were found in six of eight cases examined by Lucas and Southard.

Complications.—A not infrequent complication is otitis media (four in twelve cases, Lucas and Southard).

Sequelæ.—Of extreme importance is the prognosis. Lucas and the writer found that three cases of epilepsy developed later in a series of twenty-nine cases. In all these cases there was an apparently normal interval between recovery from the acute attack and the onset of epilepsy. This is so important that I give a brief summary of the findings in one of these cases:

January 23, 1909. Children's Hospital. F. C., aged three years.

Family History.—Father, mother and six children well and normal. No deaths, no miscarriages. An aunt is reported to be epileptic.

Past History.—Normal birth. Always well. In July, 1908 (when two and one-half years), had a convulsion for which she was given castor oil and dieted. Apparently made a speedy recovery and had been well from that time to onset of present trouble six months later.

Present Illness.—On January 20, 1909, taken sick suddenly, seemed "fretful and queer" and a few minutes later had a convulsion. Has had fifteen or twenty in three days. Has vomited once. Has been apathetic between convulsions but conscious. Has been feverish and constipated.

Physical Examination.—She was a well-developed and nourished child, very apathetic but conscious. Pupils were equal but reacted sluggishly to light. Knee-jerks could not be obtained. There was moderate rigidity of neck. There was a suggestive Kernig on the right. Spleen was not palpable. In every other way the child was normal. Her history while in the hospital was one of apparent rapid recovery. On entrance her temperature was 103°; this fell by lysis and on the ninth day was normal. Her white cell count was 23,000, taken the day after entrance. Her spinal fluid was negative. Skin tuberculin reaction was negative. She had no convulsion while in the hospital, and her mentality cleared up slowly, so that two weeks after her onset she seemed to be bright, sat up in bed, and wanted to play. Knee-jerks were very slow in returning and were still very slight when she was discharged, twenty days after the onset. She was very weak on standing and seemed unable to balance herself.

She was discharged very much relieved and apparently normal on February 7, 1909, or twenty days after her acute onset.

Subsequent History.—On writing to her parents for further information about her present condition it was learned that shortly after leaving the Children's Hospital she had a return of convulsions and had been sent to the Hospital Cottages for Children at Baldwinville, Mass., where she rarely went more than three or four days without an attack. On the days on which the attacks occurred she usually had more than one, often three or four, and they were severe. During her stay, there was a marked lengthening of the interval between the attacks, and diminution in the severity of them. In the last three months of observation, she has had only four slight attacks.

Another important sequela is a moderate degree of feeblemindedness or what the English writers term "imbecility." Over twenty-five per cent. of our series yielded marked mental defects. Some fifteen per cent. more of the cases reacted later by excessive nervousness and by increased fatigability.

Strabismus persists in two of twenty-nine cases. Mental *normality* as carefully investigated by subsequent examinations has been demonstrated in six of twenty-nine cases.

How far these cases of encephalitis are responsible for epilepsy and feeblemindedness in the community cannot be established, but it would appear that there is a small but definite group of such postencephalitic cases which bear some resemblance to institutional cases of syphilitic origin. These groups, together with a small group of traumatic cases, will doubtless fail to show the high index of hereditary taint which the usual cases of epilepsy and feeblemindedness are now thought to show on the basis of the work of the Eugenics Record Office. Our study of this problem does not show that these cases have a higher index of hereditary taint than that of the general population.

Diagnosis.—The diagnosis of acute encephalitis is not often successfully made and often not made until the autopsy. The diagnosis is rendered more accurately in children's clinics, owing to the greater proportion of cases in children, and under epidemic conditions when special consequence is attached to cases with neurological symptoms. Many of the diagnostic features are negative, yet not even lumbar puncture fluid which shows no leucocytes of blood or bacteria must be considered as excluding the possibility of hemorrhagic encephalitis, since the lesions may be central and so placed as not to pour these elements into the fluid. Stiff neck, retraction of the abdomen and hyperesthesia are not common symptoms in encephalitis, nor has herpes been reported. The diagnosis frequently depends on the association of the unusual monoplegia or hemiplegia with successive involvement during the next few hours of more and more parts of the body. Aphasia may often develop as a later but not as an unusual symptom in the disease. This is to be accounted for by the oozing of the hemorrhage or infiltration of the purulent lesion as the case may be.

In differential diagnosis we must consider: (1) Other intracranial infective diseases, such as meningococcus meningitis, tuberculous meningitis, pyogenic meningitis, and sinus thrombosis; (2) brain tumor and brain syphilis; (3) cerebral hemorrhage and focal encephalomalacia; (4) certain conditions of cerebral intoxication resembling meningitis but anatomically negative; and (5) rarely acute poisoning, hysteria, and other diseases.

The differential diagnosis in the first group, *intracranial infective diseases*, is greatly aided by lumbar puncture with microscopic examination of the cells in the centrifuge deposit, and with bacteriological examination. This, in doubtful cases, should include an attempt to grow the influenza bacillus on blood media. The finding of blood in the lumbar puncture fluid may suggest chronic internal hemorrhagic pachymeningitis and cerebral hemorrhage as well as acute hemorrhagic encephalitis. Nor will every case of hemorrhagic encephalitis show blood in the cerebrospinal fluid. Blood obtained through technical accident from the vessels at the point of puncture must not be regarded as indicating true intraventricular hemorrhage. A careful cytological examination, preferably by Alzheimer's or some similar method, should be performed. Examinations for the tubercle bacillus, meningococcus, and other pyogenic bacteria should be made.

The acute onset, the drowsiness or tendency to coma, vomiting, convulsions, and optic neuritis offer no points in differential diagnosis against meningitis, nor can much weight be placed upon the condition of the pulse or respiration.

As against *sinus thrombosis* the stasis of blood in

the veins of the face has been mentioned by Macewen, but this is not always present. Sinus thrombosis runs a very acute course. The differentiation often fails, except in middle-ear disease.

With respect to the differential diagnosis from *brain tumor*, the onset, the fever, and rapid course are important. Hemorrhagic encephalitis rarely shows an altogether characteristic tumor syndrome. Oppenheim especially warns against the immediate diagnosis of brain tumor in cases showing attacks of cortical epilepsy.

Cerebral *intoxication without anatomical signs* (the so-called pseudomeningitis of Krannhals) gives rise to the diagnosis of encephalitis, although more often to the diagnosis of meningitis, in some cases. Krannhals' cases occurred in the influenza pandemic of 1889 to 1890. The occurrence of focal symptoms would ordinarily exclude this diagnosis. Poisoning was considered in one of the writer's cases (*Staphylococcus pyogenes aureus*) of bacterial apoplexy, which ran an acute course of three days. Attention to the acute infective feature of encephalitis will usually exclude the diagnosis of *hysteria* with certainty. *Uremia* and *acetonemia* may need to be considered.

Concerning the differential diagnosis of some of the residuals of encephalitis, Dr. James Taylor has given valuable data to distinguish the following varieties:

Hemiplegic forms, resulting from encephalitis, vascular lesions and injury.	Acute encephalitis, infantile hemiplegia, infantile monoplegia, idiocy with cranial asymmetry, choreiform hemiparesis, hemiathetosis.
Diplegic forms, resulting from death of cortical cells.	Generalized rigidity, idiocy with general rigidity, paraplegic rigidity, spastic facial diplegia, amaurotic family idiocy, bilateral athetosis, choreiform diplegia, epileptiform myoclonus.

Only the diseases mentioned by Taylor of hemiplegic forms are considered by him to be of encephalitic origin.

Treatment.—It is hardly possible to systematize the treatment of these cases. I repeat some general statements made concerning the treatment of encephalitis in a contribution to Osler's Modern Medicine:

"The febrile nature of hemorrhagic encephalitis indicates certain general measures. Although the hemorrhages are, as a rule, of an oozing character, and the progress of focal symptoms depends rather upon spread of inflammatory lesions than upon massive hemorrhages, it is, nevertheless, desirable to avoid any drug treatment which may stimulate the heart. The patient should rest in bed with the head higher than the trunk, and shielded from light and noise. In the somnolent or comatose condition especial attention must be paid to the administration of food and the evacuation of the bladder and intestine. Incontinence occasionally occurs. Cold compresses or ice-bags may be applied to the head. Except in cases of chlorosis, venesection or leeches in the temporal or mastoid region are said to have given good results (Oppenheim). Drug treatment is unsatisfactory. Restless patients may require various narcotics or moist packs. Oppenheim warns against surgical treatment and even against lumbar puncture. It appears that there have been few surgical attempts at alleviation of this disease. It might seem that, were accurate localizing diagnosis possible in certain cases of massive hemorrhage, surgery would be helpful. A case of traumatic subcortical hemorrhage reported by Cushing, 1907, gives a hint in this direction; and cases are undoubtedly seen at autopsy in which evacuation of a clot would have been possible. In general, however, surgeons are doubtful of the value of surgical intervention in encephalitis. Auvray speaks of the difficulties in the differential diagnosis of nonsuppurative encephalitis and brain abscess, but would not intervene in encephalitis. Operation in meningoencephalitis (Macewen's case) has been done, and Oppenheim calls attention to Hahn's case (1896), in which trephining was performed under the false impression that abscess or hemorrhage of traumatic origin was present.

"Since, in the future, our diagnoses of encephalitis must improve in the line of etiology, it is possible that especially in the influenzal and pyogenic groups the possibilities of immunization and opsonic treatment may be exploited. The somewhat rare chance of a syphilitic encephalitis must be considered."

E. E. Southard.

Encephalocele.—See *Cephalocele*.

Enchondroma.—See *Chondroma*.

Encystina.—A subtribe of Hartman's tribe *Binucleata* in the Protozoa, in which the oökinete becomes encysted. This group includes trypanosomes, plasmodia, and Herpetomonidæ. See *Protozoa*.

A. S. P.

Encystment.—A resting stage in the life cycle of many animals during which they exist within a resistant envelope. Such stages are found in protozoans, flat-worms, rotifers, and other animals.

A. S. P.

Endocarditis.—Endocarditis is an inflammation of the endocardium, that is, of the membrane lining the cavities and valves of the heart. In the great majority of cases the valvular endocardium alone is involved.

Classification.—Endocarditis is divided into two large classes, acute and chronic. We shall confine ourselves chiefly to a description of the acute form. Chronic endocarditis is practically synonymous with chronic valvular disease of the heart. Acute endocarditis has been divided into two groups, the malignant and the simple acute type. These two types are differentiated both clinically and pathologically but the distinction is one rather of degree than of kind, since in a large collection of cases all stages between the two may be represented. Also the same bacteriological cause may be present in both varieties.

History.—Vieussens in 1715 described lesions of the valves occurring in the form of warty or cauliflower excrescences or vegetations, which prevented the closure of the valves. Bouillaud first recognized endocarditis as a distinct disease, publishing an account of it in his work on the heart and vessels in 1824. The discovery of the stethoscope by Laennec made it posssible to recognize endocarditis during life. In 1814 Kreysig of Dresden devoted special attention to inflammation of the lining membrane of the heart. Bouillaud at about this time, with the aid of the stethoscope, was able to localize the endocarditis on certain valves and declared that there was a close relationship existing between endocarditis and rheumatism. Virchow described the process of embolism and in 1869 Heiberg and Virchow demonstrated microscopically the presence of bacteria within the vegetations. In 1883 Weichselbaum cultivated staphylococci and streptococci from endocardial vegetations, and his pupil Wyssokowitch produced them experimentally in animals by the injection of bacteria into the blood. Since that time our knowledge of the etiology of the disease has been largely increased by numerous bacteriological investigations.

Etiology.—Acute endocarditis is probably in all cases a product of bacterial activity. The most im-

portant infective agents are the cause of rheumatic fever, the pyogenic cocci, the pneumococcus, the gonococcus, the bacillus of influenza, and the spirochete of syphilis. The bacilli of typhoid fever, anthrax, and diphtheria and the colon bacillus are less frequent causes. True tuberculous endocarditis is rare though it has been produced experimentally in animals. Mechanical or toxic injury is an important factor in bringing about the lesion on the valve. Since the time of Bouillaud rheumatism has been recognized as the most important and most frequent cause of endocarditis, though strictly speaking rheumatism is not a cause but an associate. Both diseases are due to infection with the same organism though what that organism is has not yet been determined. Closely associated with rheumatism are chorea and tonsillitis and it is probable that the same bacterial cause is often behind all three. The pyogenic cocci may cause an endocarditis in association with scarlet fever, diphtheria, infected wounds, puerperal fever, or septicemia. Endocarditis not infrequently appears as a complication in pneumonia and the importance of the gonococcus as a cause is growing rapidly. When occurring as a terminal manifestation in diabetes, nephritis, cancer, etc., it is due to infection which has occurred because of the patient's lowered resistance. Syphilis has not been demonstrated as a cause of acute endocarditis but does produce many cases of aortic insufficiency so that it is possible that the acute condition does occur.

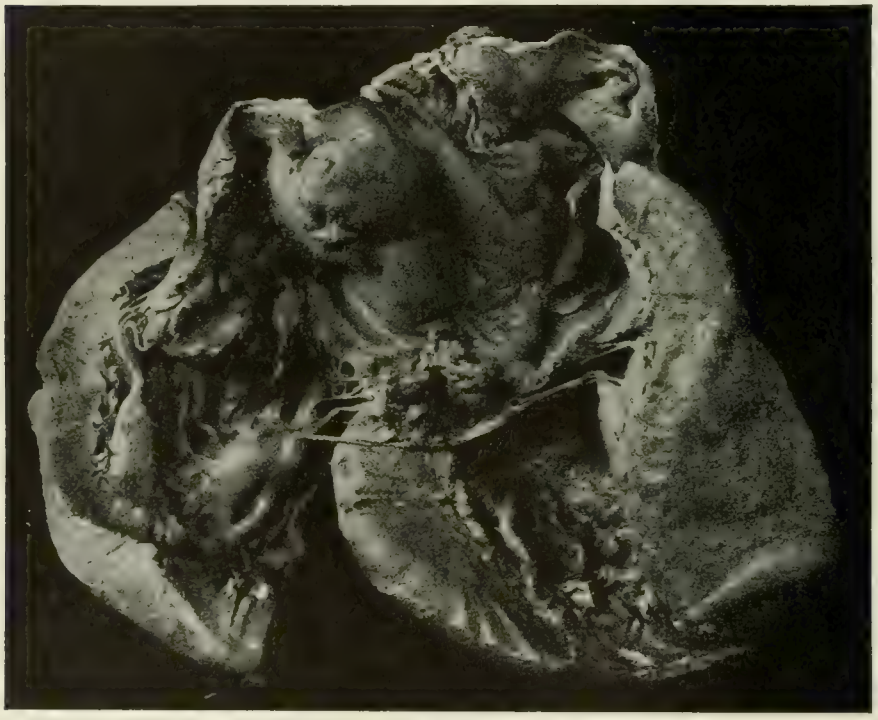

Fig. 2032.—Malignant Endocarditis Involving the Mitral Valves and the Left Auricle. (Original.)

Pathological Anatomy.—Pathologically, the difference between the malignant and the simple endocarditis is merely the usual difference between a mild and a virulent infection of any tissue. As a rule the lesion is restricted to the endocardium of the valves though it may appear on any part of the heart lining. The process begins with injury of the endothelium followed by infection. There is a rapid development of a fibrinous exudate which soon presents the grayish yellow ragged appearance which is recognized as a vegetation. These vegetations may be minute and numerous, resembling venereal warts, or so large as to resemble an extensive cock's comb. Microscopically, they consist of a superficial layer of coagulated fibrin, in the upper layer of which are entangled numbers of leucocytes deposited from the blood stream. Deeper down is a layer of simple fibrin free from corpuscular elements and below this again is a layer of granulation tissue. The development of this exudate varies with the virulence of the bacterial cause. If the virulence is high the lesion is large and may spread to the walls of the heart. The necrosis may extend to the deeper tissues and result in a perforation or aneurysm of a valve. The vegetation is rich in polynuclear leucocytes and under the influence of ferments which these cells secrete, portions of the mass become liquefied and their attachment loosened so that they are easily swept off as emboli by the force of the blood stream. Such emboli vary in size and cause infarction or abscess formation in the tissues in which they lodge. When the virulence is low the ulcerated area becomes walled off with leucocytes and gradually organization takes place. The endothelium grows out over the injured surface and under favorable conditions forms again an intact covering. This probably does not occur regularly for it is known that a valve which has once been injured is more susceptible to infection. With the subsequent contraction of the newly formed fibrous tissue occur those deformities of the valve which are characteristic of the so-called valvular disease of the heart.

Symptomatology.—The malignant form of acute endocarditis has been divided into three types which have been recognized clinically. The septicemic type is the most common and typical. It is characterized by prostration, anorexia, malaise, frequently headaches and shaking chills. The temperature is often of the septic variety with wide excursions. The skin is sallow and there is rapidly progressing anemia and loss of weight. The cheeks are sunken, the skin dry and the tongue dry and furred. The lungs may be clear or show bronchopneumonia, the respirations are rapid. The signs over the heart are variable. In some cases the only abnormality is the increased rate. Murmurs of all kinds and in all places may be heard and often change markedly from day to day. The pulse is small, weak and rapid, and the blood pressure is low. Pericarditis may develop with its sign. There is sometimes edema of the extremities. In addition there may be present the symptoms of embolism which vary according to the organ affected. The spleen is the most frequent site of such infarctions. The blood count shows a diminution in the number of the red cells which may be extreme. There is almost always a leucocytosis and a polynucleosis. Cultures of the blood are positive in about ninety per cent. of

the cases. The urine usually contains albumin and casts and often there is definite blood due to infarction of the kidney.

The typhoidal type is characterized by a more or less continuously high fever, delirium, dry tongue, distended abdomen, roseola, splenic enlargement, and possibly diarrhea, but no definite localizing symptoms. The differentiation from typhoid fever is often possible only by means of the blood culture.

In the cerebral type the symptoms due to embolism of the brain and usually of the left middle cerebral artery dominate the picture. There is a history of onset with chills and fever and then a sudden development of hemiplegia and perhaps unconsciousness. Purulent meningitis may develop.

There is a chronic form of malignant endocarditis which may last several months. It is characterized by asthenia, a moderate degree of remittent or intermittent fever, chills, petechiæ, and changing heart signs. There is progressive anemia with gradual loss of weight. The leucocytes are increased but usually not beyond 15,000. A positive blood culture may not be obtained until after several attempts. In this type of endocarditis the *Steptococcus viridans* has been found more frequently than any other organism.

Fig. 2033.—Malignant Endocarditis; Ulceration of the Aortic Valves; Hole through One of the Valves; Old Atheroma. (Original.)

The symptoms of simple acute endocarditis are primarily those of the accompanying rheumatic disease. The onset of the cardiac complication may be marked by pain and collapse. The rise in fever may be very slight. The sudden appearance of a heart murmur or the symptoms of embolism may be the first evidence of implication of the heart. There is sometimes precordial bulging in children.

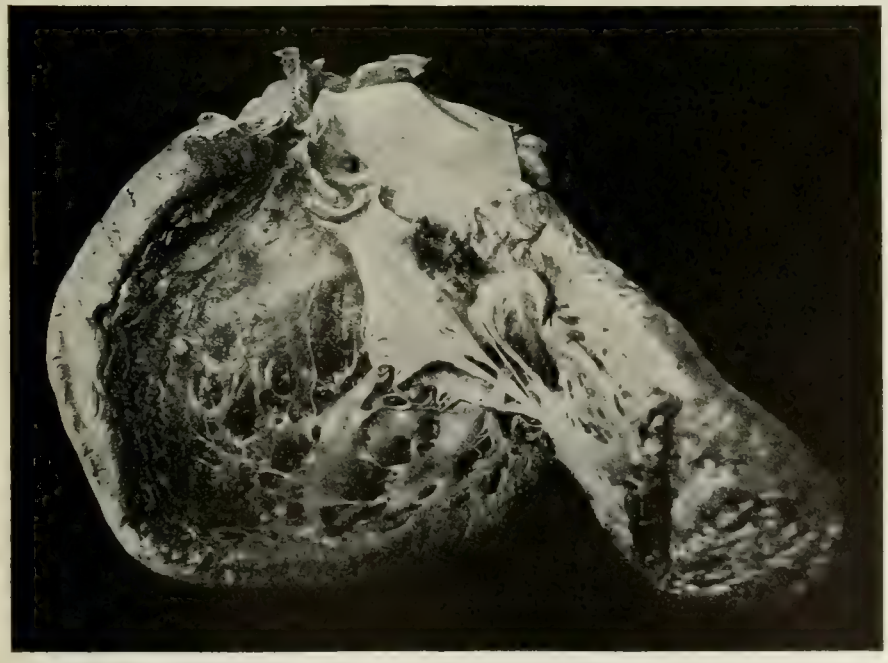

Fig. 2034.—Malignant Endocarditis; Destruction of Aortic Leaflet; Old Thickening of Aortic Valves; Dilatation of the Left Ventricle. (Original.)

Differential Diagnosis.—In the simple acute type the associated disease should lead to expectation of cardiac involvement and the characteristic signs should be recognized as they appear. In the malignant type the blood culture is the most important single diagnostic measure. The differentiation from pneumonia and from typhoid fever may be very difficult and depend entirely upon the findings in the blood. If in the course of an acute disease a murmur develops under our observation, which cannot be accounted for by anemia or weakness of

the cardiac wall, and especially if it is accompanied by an increase in fever, we are justified in diagnosing endocarditis.

Prognosis.—In the vast majority of cases simple acute endocarditis entails no immediate danger. The lesions heal to a greater or lesser extent and the subsequent cicatricial contractures result in valvular defects which may prove fatal long afterward. In malignant endocarditis, death may take place in three days, or, as when due to *Str. viridans*, only after ten to fourteen months. The prognosis is always unfavorable but in some instances recovery does occur and the patient acquires a valvular disease of the heart.

Treatment.—The treatment of simple acute endocarditis is first of all the treatment of the associated disease. The salicylates should be given in doses sufficient to control the arthritic pain but they are said to have a certain amount of depressing effect upon the heart. Rest is all important. Digitalis is the most important single drug and strychnine may often be used to advantage. The diet should be especially nutritious and iron may be indicated in order to combat the anemia. Arsenic is also used for this purpose. One of the most important prophylactic measures consists in the removal of tonsils which are subject to recurrent inflammation. The removal should of course be done in the interval between attacks. It is sometimes very striking to see the improvement in a patient following the removal of susceptible tonsils. The care of the teeth in order to prevent caries and pyorrhea is also very important. The treatment of malignant endocarditis is that of any form of general septicemia; absolute rest, light diet, and an ice-bag over the precordium to quiet the action of the heart. Drugs are of little value and sometimes the heart is so damaged that attempts at stimulation are actually harmful. Intravenous infusions of collargol and other antiseptic solutions, and the administration of Marmorek's antistreptococcus serum have proven of no value. Inoculation with bacterial vaccines, more especially autogenous ones, has apparently resulted favorably in a small percentage of cases but the disappointments have been many. The administration of filtrates of cultures of one or more organisms, the so-called phylacogens, has little to recommend it theoretically and there has as yet been no convincing demonstration of beneficial results following their use.

The effects and treatment of chronic endocarditis are those of chronic valvular lesions and will be considered under that heading.

James Rae Arneill.
Revised by Ralph G. Stillman.

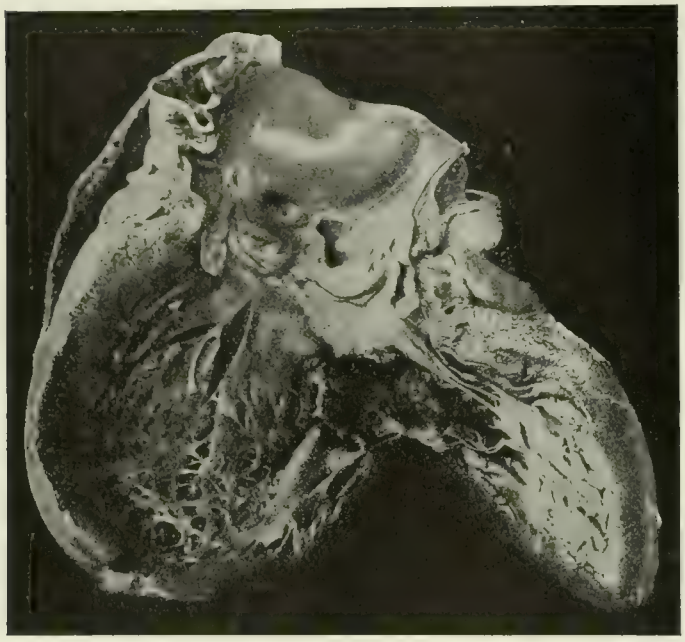

Fig. 2035.—Malignant Endocarditis on Top of Old Sclerosing Process. Marked involvement of the mitral valves. (Original.)

End-organs, Nervous.—The nervous end-organs fall into two groups which have very appropriately been termed by Sherrington the receptors and the effectors, the former being the nervous endings in the sense organs and the latter the endings within the organs of response—muscles, glands, etc.

The body is surrounded by a complex of manifestations of energy which impinge upon its surface, some of which are noxious, some beneficial, and others indifferent. Those sense organs which respond to the action of these external agents are termed exteroceptors, in distinction from the interoceptors which are stimulated by internal (chiefly visceral) processes.

We are surrounded by many forms of external energy to which our receptive end-organs are entirely insensitive, such as ultraviolet rays from the sun, Hertzian electric waves, etc. Receptors have been differentiated only for those forces of our natural environment which can either benefit or injure the body; to the rest we are entirely indifferent. The purpose of the receptors, then, is to analyze the environing energy complex in such a way as to facilitate the execution of the adaptive or useful modes of response to all significant environmental factors. This is accomplished, as Sherrington points out, by lowering the stimulus threshold of each receptor for some one kind of energy manifestation and raising it for all others; or, otherwise stated, each receptor is attuned to respond only within a definite range of energy manifestations and to remain silent to all others.

An acceptable classification of the receptors or sense organs of the body must take account of their anatomical relations, of the nature of the physical or chemical forces which serve as the adequate stimuli, of the subjective qualities which we experience upon their excitation, and of the character of the physiological responses which commonly follow their stimulation. The last point has been too much neglected.

In fact, the most fundamental division of the nervous system which we have, cutting down through the entire bodily organization, is based upon this physiological criterion. Sherrington, whose analysis with some modifications is here adopted, recognizes three types of sense organs, or receptors: (1) the interoceptors, or visceral receptive organs, which respond only to stimulation arising within the body, chiefly in connection with the processes of nutrition, excretion, etc.; (2) the exteroceptors, or somatic sense organs, which respond to stimulation arising from objects outside the body; (3) the proprioceptors, a system of sense organs found in the muscles, tendons, joints, etc., to regulate the movements called forth by stimulation of the exteroceptors. This third group is really subsidiary to the somatic system, or exteroceptors, and will be considered more in detail beyond. The important point to bear in mind here is that stimulation of the visceral sense organs typic-

ally calls forth visceral responses, *i.e.* adjustments wholly within the body, while stimulation of the somatic (exteroceptive) sense organs typically calls forth somatic responses, *i.e.* a readjustment of the body as a whole with reference to its environment. This is a very fundamental distinction.

From this standpoint the nervous system has a two-fold part to play in the vital economy. In the first place, the nervous system is the chief organ by which the correlation or "correspondence" (Herbert Spencer) of bodily and environmental forces is maintained. And in the second place, the nervous system has the important function of the internal regulation of the parts of the body *inter se*, to ensure their proper nutrition and continued well-being. These two functions are quite diverse and the organization of these two parts of the nervous system shows corresponding structural differences.

We divide the nervous organs, then, into two great groups, the exteroceptive or somatic group, and the interoceptive, visceral or splanchnic group. The latter group comprises the nerves and nerve centers concerned with digestion, respiration, circulation, excretion and reproduction. These are chiefly found within the sympathetic nervous system and those parts of the central nervous system directly connected therewith, though the more highly specialized members of this group are independent of the sympathetic system. The exteroceptive or somatic group comprises the greater part of the brain and spinal cord and the cerebral and spinal nerves, or briefly, the cerebrospinal nervous system, as distinguished from the sympathetic system. This is the mechanism by which the body is able to adjust its own activities directly in relation to those of the outside world—to procure food, avoid enemies, and engage in the pursuit of happiness.

Fig. 2036. — Tactile Nerve Endings in the Deep Layer of the Cutis from the Nose of a Cat. (After Botezat.)

The organs belonging to each of these two groups do much of their work independently of the other group; *i.e.* visceral stimuli call forth visceral responses and external or somatic stimuli call forth somatic responses. Nevertheless the two groups of organs are by no means entirely independent, for external excitations may produce strong visceral reactions, and conversely. Thus, the sight of luscious fruit (exteroceptive stimulus) naturally calls forth movements of the body (somatic responses) to go to the desired object and seize it. But if one is hungry, the mouth may water in anticipation, a purely visceral response. On the other hand, the strictly visceral (interoceptive) sensation of hunger is apt to set in motion the exteroceptive reactions necessary to find a dinner.

With these principles in mind, let us now undertake an analysis of the human sense organs and of their effectors. The following list is by no means complete and is in some parts merely provisional.

I. Somatic Senses.—These are senses concerned with the adjustment of the body to external or environmental relations.

A. Exteroceptors.—Stimulated by objects outside the body and typically evoking reactions of the whole body, such as locomotion, etc. This group includes a very complicated system of general cutaneous sense organs, some organs of deep sensibility, and some of the higher sense organs. The cutaneous exteroceptors comprise a complex system whose analysis has proven very difficult. The conclusions presented in the paragraphs which follow are based chiefly upon the observations of von Frey and Henry Head. The correlation of the data of physiological experiment with the anatomical structure of the cutaneous end-organs is still somewhat problematical and the structures assigned here to the various cutaneous senses should be regarded as provisional rather than as demonstrated.

1. End-organs of the pressure or tactile sense. These fall into three groups distinguished by Henry Head as epicritic, protopathic, and deep sensibility. Epicritic tactile sensibility is a highly refined type, regarded as of later evolutionary origin than the other two. It includes light touch on the hairless parts of the body particularly. Cutaneous localization ("spot-naming") and the discrimination between two points simultaneously stimulated ("the compass test") are functions of this system. The threshold for pressure stimuli is lower than in the case of direct stimulation of the protopathic and deep end-organs. The receptive organs are special tactile bodies, such as Meissner's corpuscles. They are generally found in the cutis and subcuticular tissues, either as free skein-like terminal arborizations of medullated cutaneous nerves or as similar more elaborate endings enclosed in connective-tissue capsules. Fig. 2036 illustrates a simple form of these endings in the cutis of the nose of a cat, and Fig. 2037 a more complex endings, partly within the perichondrium and partly within the cutis from the same region. The Meissner's corpuscles (Fig. 2038) are the most characteristic tactile endings of this system in the human body, consisting of a similar skein of nerve termini enclosed within a connective-tissue capsule.

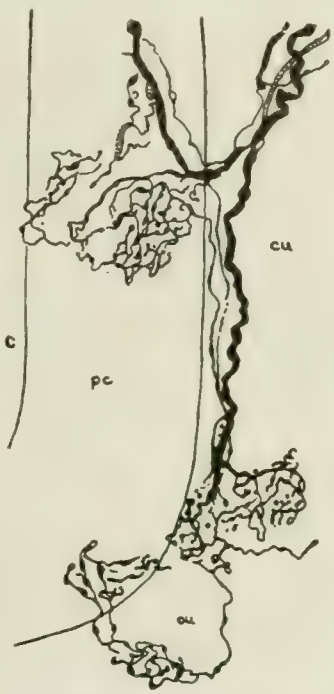

Fig. 2037.—Complex Nerve Endings, from the Nose of a Cat. (After Botezat.) The apparatus lies partly in the cutis *cu*, and partly in the perichondrium *pc*, above the nasal cartilage *c*.

Protopathic tactile sensibility is a more primitive type of general diffuse touch, especially well developed on the hairy parts of the skin. These sensations have no clearly defined local sign, and yet their end-organs are themselves definitely grouped about the hair bulbs. The hairs are the most important sources of excitation of these organs and the sensitiveness of hair-clad parts is greatly reduced after the hair is shaved. "The liminal stimulus for the touch spots about a short hair is three to twelve times greater than for the hair itself, *i.e.* the hair is three to twelve times more sensitive than the spots" (Sherrington).

The innervation of the hair bulbs is very complex and varies greatly for different animals and for the different kinds of hairs on the same body, so that no

Fig. 2038.—Meissner's Tactile Corpuscle from the Cutis of the Human Skin. (After Dogiel from Böhm-Davidoff-Huber's Histology.)

general description is possible. The large vibrissæ of the rat receive their nerve supply from two sources (Vincent, 1913). A large nerve bundle pierces the

Fig. 2039.—Straight and Circular Nerve Endings on the Root of a Soft Hair from the Lower Lip of a Man 49 Years Old. (After Szymonowicz.) The coarser forked endings belong to the straight system and the finer fibers to the circular system.

dermal sheath in the lower part of the bulb, spreads out over the inner follicle in a heavy plexus, and terminates chiefly in a mantle of touch cells, resembling Merkel's corpuscles, in the outer root sheath all over the follicle. A second nerve supply comes from the dermal plexus of the skin, from which branches run down and form a nerve ring about the neck of the follicle. Experimental studies show that these hairs are very important not only as general tactile organs, but specifically as aids in locomotion and equilibration. The ordinary hairs of man and other mammals have three forms of specific nerve endings in addition to various forms of terminal arborizations in the surrounding tissues: (1) straight and often forked endings running parallel with the base of the hair;

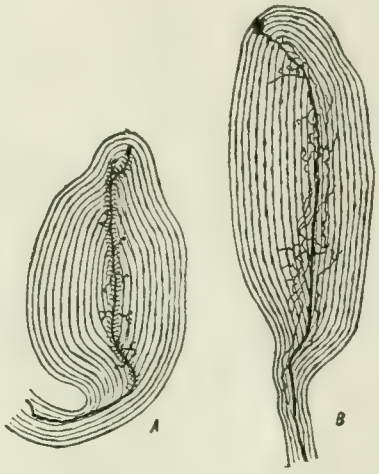

Fig. 2040.—Pacinian Corpuscles from the Mesorectum of a Cat. (After Sala from Böhm-Davidoff-Huber's Histology.)

(2) circular fibers forming a plexiform ring around the root of the hair external to the straight endings; and (3) leaf-like nerve endings associated with special cells resembling Merkel's corpuscles. Fig. 2039 illustrates the first and second types of these endings.

The deep pressure sense is served by special nerve endings throughout the tissues of the body and is preserved after loss of all cutaneous nerves. By these end-organs relatively coarse pressure may be discriminated and localized and movements of muscles and joints can be recognized. Most of the functions of the deep sensory nerves belong to the interoceptive and proprioceptive series (see beyond), but some

Fig. 2041.—End-bulb of Krause from the Conjunctivum of Man. (After Dogiel from Bailey's Histology.)

exteroceptive functions are here present also. The latter are probably related chiefly to the Pacinian corpuscles and similar encapsulated end-organs. The Pacinian corpuscle has a central nerve fiber enclosed in a firm lamellated connective-tissue sheath (Fig. 2040).

2. End-organs for sensibility to cold.

3. End-organs for sensibility to heat. Physiological experiment shows that heat and cold are sensed by different parts of the skin—the warm spots and the cold spots respectively—and that each of these may be present in an epicritic and a protopathic form. What end-organs are involved here is by no means certain. The margin of the cornea was found by

von Frey to be sensitive to pain and cold only. The free nerve endings found here he assumes to be pain receptors and the end-bulbs of Krause (Fig. 2041) to be cold receptors. By an analogous argument he assumes that the "genital corpuscles" of Dogiel

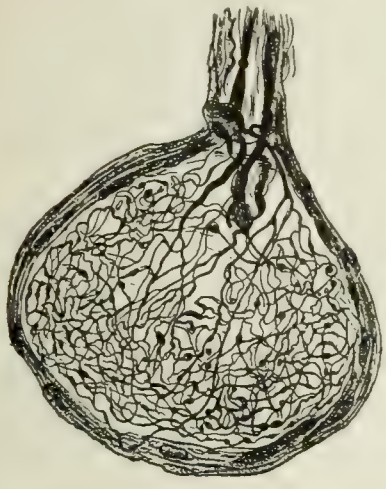

Fig. 2042.—Genital Corpuscle from the Glans Penis of Man. (After Dogiel from Böhm-Davidoff-Huber's Histology.)

(Fig. 2042) and some similar endings widely distributed in the skin are warmth receptors. By some other physiologists these two types of end-organs are regarded as belonging to the tactile system.

4. End-organs for pain. Some physiologists believe that there are separate nerve endings for pain;

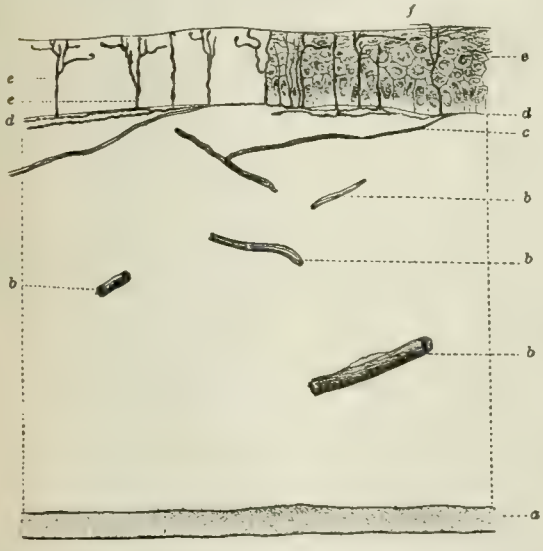

Fig. 2043.—Vertical Section Through the Cornea. (After Cohnheim from Barker's Nervous System.) The corneal corpuscles and the cells of Descemet's membrane are left out of the drawing; the anterior epithelium has been drawn only in part. *a*, Descemet's membrane; *b*, nerves from the plexuses; *c*, branches going to the epithelium, here ascending by accident very obliquely; *d*, fibers of the subepithelial layer; *e*, vertical cut threads with horizontal outrunners; end nodules can be seen; *f*, an undoubted precorneal horizontal fiber.

others regard pain as a quality which may be present in any sense, and not as itself a true sensation. The free intraepithelial nerve endings are regarded by von Frey as the pain receptors, because these endings alone are present in some parts of the body where susceptibility to pain is the only sense quality present, such as the dentine and pulp of the teeth and the cornea (Fig. 2043). Similar endings are found throughout the epidermis (Fig. 2044) and in many deep structures.

5. End-organs of general chemical sensibility. In man this is found only on moist epithelial surfaces, such as the mouth cavity; but in fishes it may be present over the entire bodily surface (Sheldon). The sense organ is probably the free nerve terminals among the cells of the epithelium, never special sense organs like taste buds, for these when present in the skin belong to a quite different system.

6. Organs of hearing. The stimulus is material vibrations whose frequency ranges between 16 and 40,000 per second. The receptor is the organ of Corti in the cochlea, perhaps also the sensory spots in the saccule and utricle. There are two forms, (1) noise, stimulated by sound concussions or irregular mixtures of aërial vibrations; (2) tone, stimulated by sound waves or periodical aërial vibrations.

Fig. 2044.—Transverse Section Through the Skin of the Ear of a White Mouse Three Days Old. (After Van Gehuchten.) *a*, horizontal fibers; *b*, bifurcation; *fn*, nerve fibers.

7. End-organs of vision. The stimulus is ethereal vibrations ranging between 392 billions and 757 billions per second. Here also there are two forms: (1) brightness, stimulated by mixed ethereal vibrations; (2) color, stimulated by simple ethereal vibrations.

8. End-organs of smell. This sense has both exteroceptive and interoceptive qualities, the latter being apparently the more primitive. See the fuller discussion beyond under the Interoceptors (Visceral Senses) and in the article *Olfactory Nerve*.

B. Proprioceptors.—These sense organs are contained within the skeletal muscles, joints, etc., and are stimulated by the normal functioning of these organs, thus reporting back to the central nervous system the exact state of contraction of the muscle, flexion of the joint, tension on the tendon, etc. These reactions are generally unconsciously performed.

9. End-organs of muscular sensibility. The organ is a series of nerve endings among special groups of muscle fibers known as muscle spindles. These endings are usually spirally wound around their muscle fibers and are stimulated by the contraction of the muscle (Fig. 2045).

10. End-organs of tendon sensibility. Similar nerve endings are spread out over the surfaces of tendons and are stimulated by stretching the tendon during muscular contraction (Fig. 2046).

11. End-organs of joint sensibility. Nerve endings found in the joints and the surrounding tissues are stimulated by bending the joint and report back to the central nervous system the degree of flexion

of the joint. The chief end-organs are probably Pacinian corpuscles.

12. Static and equilibratory sensations arising from stimulation of the semicircular canals of the internal ear (Fig. 2047). This is the most highly specialized member of the proprioceptive group and acts in conjunction with all of the other somatic senses to maintain equilibrium, posture, and the tone of the muscular system. The eyes and most of the other exteroceptive

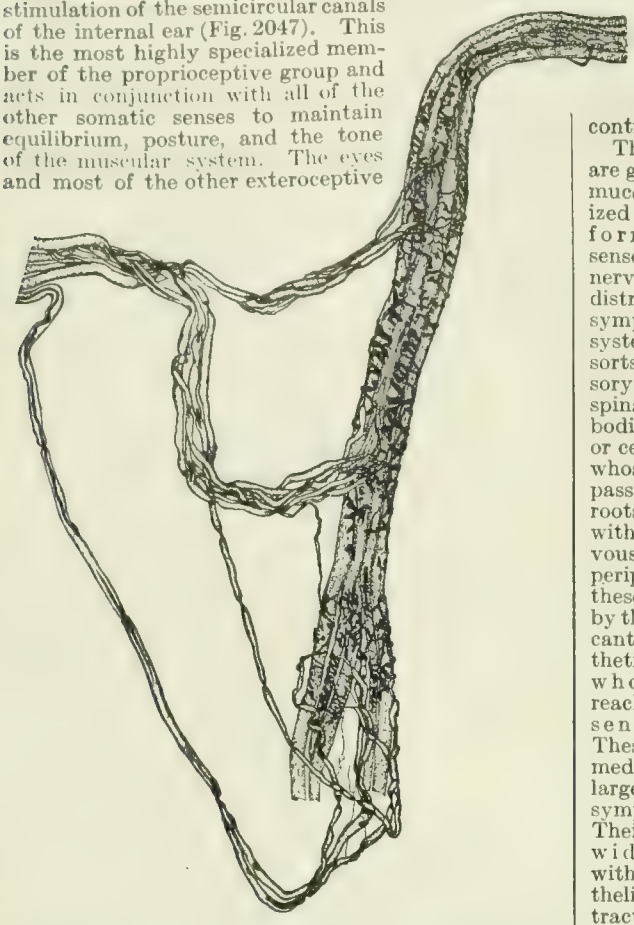

Fig. 2045.—Neuro-muscular Nerve End-organ from the Intrinsic Plantar Muscles of a Dog, from Teased Preparation Stained with Methylene Blue. The figure shows the intrafusal muscle fibers of the muscle spindle, the nerve fibers and their terminations; the capsule and the sheath of Henle are not shown. (After Huber and DeWitt.)

sense organs, so far as they act in the way just suggested, serve as proprioceptors.

II. Visceral Senses.—The visceral or interoceptive senses fall into two well-defined groups. First, the general visceral senses are without highly specialized end-organs and are innervated through the sympathetic nervous system. Their reactions are chiefly unconsciously performed. Second, the special visceral senses are provided with highly developed end-organs which are innervated directly from the brain without any connection with the sympathetic system. The special visceral sense organs may in some cases serve as exteroceptors as well as interoceptors. Their reactions may be conscious and voluntary.

A. General Visceral Senses.—13. Hunger. Stimulus, strong contractions of the gastric muscle (Cannon, Carlson). This is a variety of muscle sense.

14. Thirst. Stimulus, dryness of the pharyngeal mucous membrane (?).

15. Nausea. Stimulus, antiperistaltic reflex.

16. Respiratory sensations, suffocation, etc.

17. Circulatory sensations, flushing, heart panics, etc.

18. Sexual sensations.

19. Sensations arising from distention of cavities, stomach, rectum, bladder, etc. (muscle sense).

20. Visceral pain.

21. Obscure abdominal sensations associated with strong emotions of fright, anger, affection, etc., characterized (probably correctly) by the ancients by such expressions as "yearning of the bowels," etc. The stimulus is probably a tonic contraction of the unstriped visceral musculature.

The nerve endings of the general visceral receptors are generally free arborizations in or under the various mucous surfaces, without the development of specialized accessory cells to form differentiated sense organs. These nerves in general are distributed through the sympathetic nervous system and are of two sorts: (1) Visceral sensory fibers of cerebrospinal origin, whose cell bodies lie in the spinal or cerebral ganglia and whose central processes pass through the dorsal roots to terminate within the central nervous system. The peripheral processes of these neurones pass out by the rami communicantes into the sympathetic system through whose nerves they reach their respective sensory surfaces. These fibers are usually medullated and are the largest fibers of the sympathetic nerves. Their endings spread widely below and within the mucous epithelia of the digestive tract, bladder, etc. (Figs. 2048, 2049). (2) Besides the visceral fibers of cerebrospinal type, there are throughout the body peripheral sympathetic neurones forming a diffuse ganglionic plexus pervading all the tissues. Some of these neurones are regarded by Langley as non-polarized and serving local reflexes; others are apparently differentiated as specific motor (postganglionic) or sensory elements. Many ciliated epithelial and glandular visceral surfaces are innervated by endings which either arborize freely around the epithelial cells or end upon them with trefoil expansions (Fig. 2050). These are probably endings of this type. Unmedullated fibers of this system enter the spinal ganglia through the rami communicantes and there effect functional connections with the spinal ganglion neurones (Dogiel).

Fig. 2046. — Neuro-tendinous Nerve End-organ from the Rabbit; Teased Preparation Stained with Methylene Blue. (After Huber and DeWitt.)

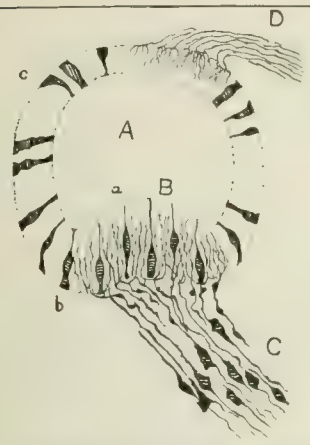

Fig. 2047.—Transverse Section of the Semicircular Canal of the Ear of a Mouse showing Terminals of the Vestibular Branch of the VIII. Nerve. (After Ramón y Cajal.) *A*, Lumen of the canal; *B*, crista acustica; *C*, bundle of nerve fibers containing bipolar ganglion cells; *D*, a similar bundle supplying the top of the canal; *a*, *b*, and *c*, varieties of bipolar epithelial cells.

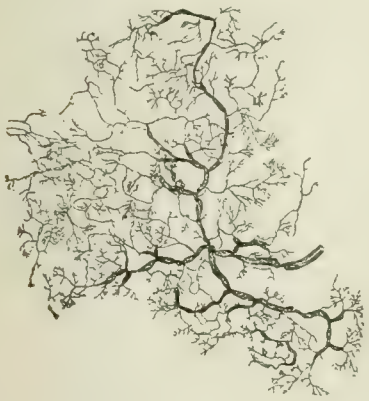

Fig. 2048.—Tangential Section of the Mucosa of the Esophagus of a Cat. (After DeWitt.)

Fig. 2049.—Free Endings of Afferent Nerve Fibers in the Epithelium of a Rabbit's Bladder. (After Retzius.) *bg*, Subepithelial connective tissue; *n*, nerve fiber entering the epithelium where it breaks up into numerous terminals among the epithelial cells; *e*, surface epithelium of the bladder.

B. Special Visceral Senses.—22. Taste. Chemical stimulation of taste buds on the tongue and pharynx by sweet, sour, salty, or bitter substances. In man

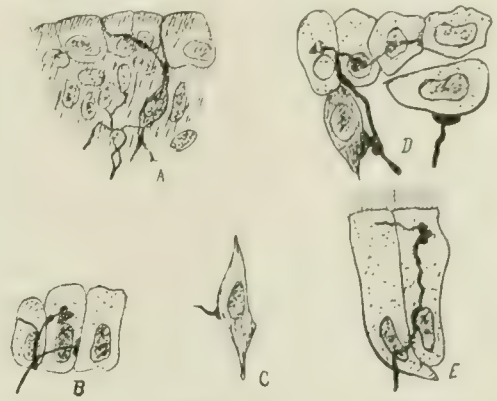

Fig. 2050.—Nerve Endings in the Mouth Epithelium of the Frog. (After Bethe.) *A*, "Gabezelle," from sensory papilla of the tongue; *B*, cylinder cells; *C*, isolated rod cell; *D*, upper part of papilla; *E*, ciliate cells of palate

this is a strictly interoceptive sense; but in some fishes taste buds are scattered over the outer body surface in addition to the mouth cavity, and thus serve as exteroceptors also. The organ is a specialized flask-shaped collection of epithelial cells of two sorts, supporting elements and specific sensory elements (Fig. 2051). There is a double innervation, partly by perigemmal fibers whose endings surround the bud, and partly by intragemmal fibers which penetrate the bud and arborize in intimate relation with the specific sensory cells (Figs. 2052, 2053).

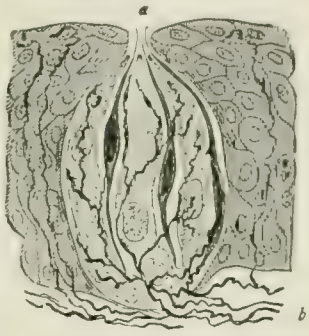

Fig. 2051.—Taste Bud from Side Wall of Circumvallate Papilla. (After Merkel-Henle.) *a*, Taste pore; *b*, nerve fibers, some of which enter the taste bud (intragemmal fibers), while others end freely in the surrounding epithelium (intergemmal fibers).

23. Smell. Chemical stimulation of the specific olfactory mucous membrane of the nose. The number of substances which may act as stimuli is greater than in the case of taste buds, the number of subjective qualities is also greater, and the discrimination threshold is much lower. That this

Fig. 2052.—*A*, Perigemmal Nerve Ending from Taste Buds of the Conger Eel; *B*, intragemmal nerve endings from taste buds of Barbus vulgaris. (After Lenhossék.)

system was originally an interoceptive sense seems clear; but in all vertebrates living at the present time the visceral responses to smell are quite subordinate to the somatic reactions. The sense of

smell is the leading exteroceptor in most lower vertebrates, and this function has been secondarily derived from the primary visceral function. We have seen above that the sense of taste in some fishes has secondarily acquired exteroceptive functions; and in the case of smell this secondary change has been carried still further until the exteroceptive function has come to dominate the primitive interoceptive, though the latter has by no means been entirely eliminated (cf. *Olfactory Nerve*).

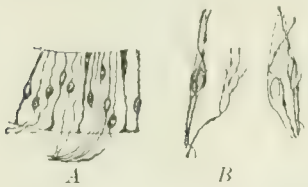

Fig. 2053.—*A*, Olfactory Nerve Endings in Jacobson's Organ (After Lenhossék.) *B*, Nerve endings in taste buds. (After Arnstein.)

The peripheral organ of smell is a specific sensory epithelium within the nose, whose sensory cells give rise directly to the fibers of the olfactory nerve, this being the only peripheral nerve of the human body whose fibers arise from superficially placed cell bodies. Jacobson's organ of many animals gives rise to a separate part of the olfactory nerve, the nervus vomero-nasalis (Fig. 2053).

III. Somatic Effectors.—24. End-organs on the striated skeletal muscles. These muscles are derived

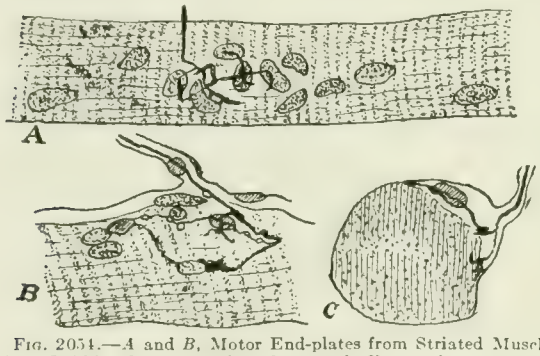

Fig. 2054.—*A* and *B*, Motor End-plates from Striated Muscle of the Rabbit; *C*, cross-section of a muscle fiber and motor end-plate of the frog. (After Huber and DeWitt.)

embryologically from the somites or primary mesodermal segments of the embryo. They are under the direct control of the will and are concerned chiefly with locomotion or other movements which change the relations of the body to its environment; they are typically stimulated to action through the exteroceptive sense organs. They are innervated by

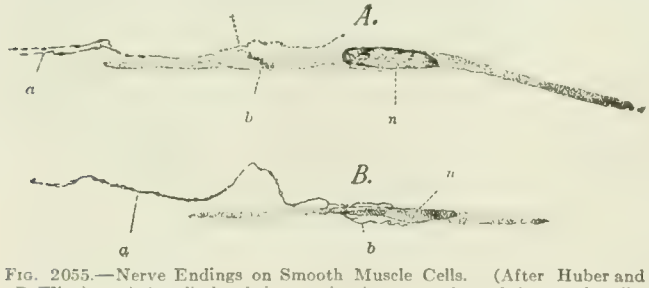

Fig. 2055.—Nerve Endings on Smooth Muscle Cells. (After Huber and DeWitt.) *a*, Axis cylinder; *b*, its termination; *n*, nucleus of the muscle cell.

a system of somatic motor nerves arising from a ventral motor column of nerve centers. The components of this system found in the cranial nerves (III., IV., VI., and XII. pairs) are sometimes distinguished as a special group, in contrast with the general somatic motor nerves of the trunk (cf. *Cranial Nerves*). The end-organ, or motor end-plate, is a complex terminal arborization of the motor nerve fiber, associated with an elevated granular mass of sarcoplasm and a collection of nuclei of the muscle fiber (Fig. 2054).

IV. Visceral Effectors.—25. End-organs on the involuntary visceral muscles. These muscles may be unstriated or striated (as in heart muscle).

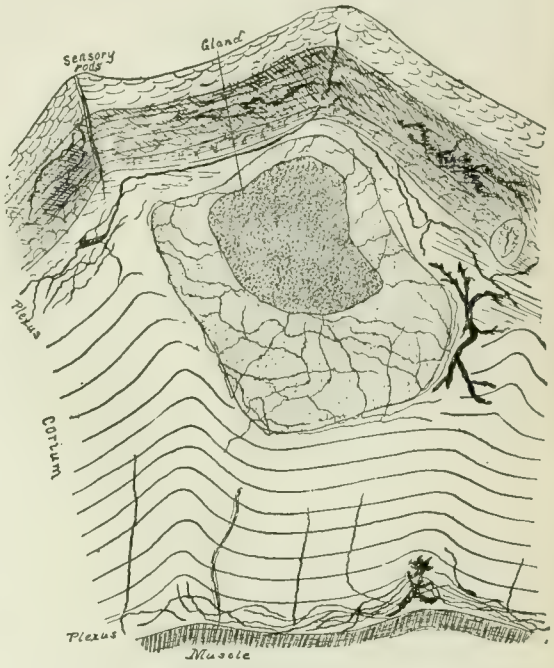

Fig. 2056.—Thick Section Through the Skin of a Toad (Bufo). Illustrating a network of fine unmedullated nerve fibers over the uncut surface of a cutaneous gland. The duct and part of the body of the gland are out of the plane of the section. (After C. L. Herrick.)

They are innervated through the sympathetic nervous system and typically by a chain of two neurones, the preganglionic and the postganglionic neurones. The body of the preganglionic neurone lies in the central nervous system and its neurite passes out into the sympathetic nervous system where it ends in a sympathetic ganglion. The efferent impulse is here taken up by a postganglionic neurone, whose body lies in the sympathetic ganglion in question and whose neurite passes onward through a sympathetic nerve to end in the appropriate effector. The nerve endings of this system are simple or branched free terminals ending on the surface of the muscle fiber (Fig. 2055); in the case of heart muscle the fibers usually have expanded trefoil tips.

26. End-organs on glands. The innervation of these organs is in most respects similar to that of the involuntary muscle last described. A fine plexus of non-medullated fibers of sympathetic origin envelops the smaller glands and pervades the larger ones (Fig. 2056); they are believed to be the excitoglandular fibers.

27. Special visceral motor end-organs. The nerves of this system have no connection with the sympathetic system. These effectors are striated muscles acting under the direct control of the will. They are derived phylogenetically from the branchial or gill muscles of lower vertebrate ancestors and they are

developed embryologically from the ventral unsegmented mesoderm and not from the primitive mesodermal segments which give rise to the somatic muscles. They are innervated directly from a ventrolateral column of motor neurones of the medulla oblongata, whose neurites form part of the motor roots of the V., VII., IX., X., and XI. cerebral nerves.

C. Judson Herrick.

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Endothelioma.—See *Sarcoma.*

Enema.—See *Enteroclysis.*

Enema, Nutritive.—See *Alimentation, Rectal.*

Energy.—This term may be roughly defined as the doing or the capacity for doing work; that which overcomes resistance; activity; the exertion of power; efficiency. It is purely a matter of one's intellectual temperament and philosophical opinions whether mental energies or energy be included for him or not in this definition. The word energy comes from the Greek adverb *energos* (meaning active), which in its turn was compounded of *en*, in, and *ergon*, work. The idea comprised in this expression "in working" is indeed very exactly the essence of the modern physical concept expressed by the word energy. One of the two great classes of energies, those of *position*, termed in physics potential energy, is of especial interest in organic energetics and therefore in medicine; the other class of energies, those of *motion*, kinetic energies, are far more obviously true energies, since they contain the root idea of activity. A man, for example, pulling upward on a ring-bolt firmly fixed in the curbstone, might exert a great amount of energy without exerting any "energy" at all on the purely physical definition of energy as "the capacity for doing work," where "work" means the overcoming of resistance through space. The nonsense of this old-time definition of work, then, as involving *space* of necessity, is at once apparent, for of all energies the energies of living organisms are the most obviously certain. If, then, such a notion of energy interferes with a definition in physics, we must give up the definition, for the expense of energy under the conditions suggested is quite undeniable.

The tendency, then, is to limit the term energies to those by physics termed kinetic, energies of motion, Potential energy, that imagined as inherent in position, is less obviously energy or even something else, in a sense, being a wholly relative matter, relative namely to space. On the other hand real or obvious energy may be, as we have seen by the illustration above, wholly independent of space, especially in organisms. The relations here are metaphysical and recondite to a degree, and taken together suggest how intimately derived from our own exertion is our concept of energy.

No definition of energy, for example "the capacity to do work," is satisfactory which is so utterly relative that it fits only a part of the instances. Suppose, for another instance, a stone carried to the summit of a granite mountain and thrown into a vertical hole drilled out of the rock there; the conventional physicist would say it had "acquired the (potential) energy required to lift it from its original place, and that if the mountain were removed this energy would show itself as kinetic energy and draw it toward the center of the earth." Certainly this stone in its new position has no velocity of its mass; on the other hand, to define its acquired (potential) energy as due to strains is to ascribe it not to itself but to the earth which somehow tends to attract it into its midst. The conventional physicist seems to be content with the old-time definitions of his science, however, although he cannot well help being puzzled at times by their inconsistencies. We may well rest with an opinion not unlike that of the well-known English philosopher, F. H. Bradley: "No one is bound to be intelligible outside his own science, I am quite convinced as to that." It is not any too pleasing, none the less, to see glaring inconsistencies (compare the conservation of energy doctrine taken as an absolute law!) concerning the one ultimate thing (energy) with which the science is properly concerned.

Not only in such respects, but in others, is the idea of energy commonly held by the world at large at present in a state of fusion not to say confusion—fusion with other concepts, confusion because of the discovery of radium and its emanations, together with the doctrine of the "electrons" and of the "structureless" ether between them. Yet even here we may not rest, because scientists and thinkers as valid as the learned world has produced do not hesitate to think of consciousness as a form of energy and indeed as the most pervasive of all its forms. We are at a loss for answers to all these indefinitenesses concerning the limitations of the energy-concept, and consequently can do no better, perhaps, in the entire absence of authority (because authorities conflict) than to attempt a brief discussion of the most obvious of the various phases of energy, so far, especially, as medicine is concerned with them.

Whether in part hereditary or (according to John Locke) entirely the result of personal experience during infancy (the former seems the more likely supposition), the human concept of energy must originate wholly, either at first-hand or at second-hand, from the direct expenditure of energy by our muscles under the stimulation of our coordinating cerebral (voluntary) nerve impulses. Here alone do we come in direct relationship with the expenditure of force—but here we experience this very thing continually. Our whole life is, in fact, a series of experiences of this phenomenon as a manifestation of irritability; in many respects it is most unfortunate that language has crystallized the concept unduly hard into what we think of as "cause and effect." At any rate, useful as is this idea in our common life as an indicator of a certain phase of empirical relationship, it is quite essential to remember that in pointing to an event or a condition as the "cause" of another event or condition we are using only a symbol of convenience for what is really a multiplicity of conditions each more or less concerned in the series of events. This obvious integrative and broadening trend in the thought, especially the biologic thought, of the day was so ably expressed by Max Verworn of Bonn in

his Silliman Lectures at Yale in October, 1911, that we can do no better than to quote his remarks at some length, as follows:

"The interpretation of the unity of being and happenings in accordance with natural laws, which to-day is widely accepted in the scientific world as the only exact one, implies the assumption of a causation according to which things are explained by the law of 'cause and effect.' I have already on various occasions taken the opportunity to criticise this view and to show the error and confusion to which it leads. I should like here to enter somewhat more in detail into the reason for this criticism. It is particularly directed against the scientific use of the term 'cause' on the basis of our best known theoretical principles. It is clear that all scientific observations and explanations are founded on experience. Can it be said that the conception of 'cause' originates from experience?

"We can say with absolute certainty that the conception of cause dates from prehistoric times. Its beginning reaches back to the stone age, at least to neolithic, possibly to paleolithic culture. This is demonstrated by the careful reconstruction of these prehistoric races based on a critical comparison of the remains of their culture with that of primitive races living to-day. The ideas of these primitive races show an inclination to an extraordinary degree to explain all happenings in the world anthropomorphously. All happenings in surrounding nature are given the same origin as the activities of man himself. To man on this plane of fantastic religious speculation all events in nature appear as the acts of will of invisible powers, which, having originally proceeded from the souls of dead human beings, think, feel, and act exactly as *he does*. This anthropomorphic conception of the occurrences in the surrounding world is one of the many conclusions which ensue from the supposition of an invisible soul, which can be separated from the body. It was this conception which gave the impetus for the transition of human thought from the era of the naïvely practical to the era of the theoretical spirit in that far removed age. In this anthropomorphic transference of personal subjective impulses of will to the objectively observed events of the surrounding world, lies the origin of causal conception, which since then has been generally used as the explanation of the happenings in the world. One cannot assert that the formation of the conception of cause is purely a product of *experience* but rather a result of *naïve speculation*. Even if a later evolution of human thought shows a continued endeavor to dismantle the conception of cause of its primitive trappings, and to modernize, as it were, its outer appearance, we still find today many inner components clinging to it, which do not agree with the strict demands of critical scientific exactness, demands which must particularly be made concerning a conception which has been given such fundamental importance in theoretical knowledge.

"I wish to observe here, however, that the conception of cause, even though more or less unconsciously so, is still the remains of a part of the old anthropomorphic mysticism carried over into our own times. This shows itself especially in the conception of *force*, which is nothing more than a form of the conception of cause [and of energy]. Force is the cause of movement. One has here in anthropomorphic manner transferred the action of the *will* of man, which produces movement of the muscles, into lifeless nature. The force of the sun attracts the earth, that of the magnet attracts iron, etc. In short, one has introduced a mysterious unknown factor instead of being content with the simple description of facts such as G. Kirchhoff ('Vorlesungen über mathematische physik. Mechanik,' Leipzig, 1876) has advanced in the field of mechanics. Although of late natural science has also dispensed more and more with the conception of force as a means of explanation, it is still to-day not wholly done away with."

We might continue the history of this "naïve speculation" as to the notion of energy, force, and cause, and be still more sure at the end that our conception of these arose wholly in our own expenditure of energy in our organism, product of hundreds of thousands of years of quasi-human evolution. It will be better, however, to try to obtain a notion of the concept of energy as held by its actual employers in their scientific work.

As a chance example of the research which is tending to demonstrate the unity of the "different kinds of energy" described by the former conventional physicist (surer of his principles than of his own actual experience), we may quote part of the summary and conclusions from experimental work on the mechanical efficiency of muscle done by A. V. Hill of Cambridge University and reported in the *Journal of Physiology* for August, 1913 (xlvi., 6): "It is concluded that under certain conditions the initial process of contraction consists largely if not entirely of the liberation of free potential energy, manifested as tension energy in the excited muscle; that this potential energy can be used indifferently for the accomplishment of work or the production of heat; that, including the recovery process, the efficiency of the whole muscular process may be almost as high as fifty per cent.; that the muscular machine is one in which free energy, prospective mechanical or potential energy, is stored in certain unstable chemical compounds, under the influence of preliminary chemical processes carried out in the presence of oxygen with the evolution of heat; and that after activity these unstable chemical compounds are rebuilt; that the chemical body possessing this free energy is the lactic acid precursor; and that under some conditions, *e.g.* high initial tension and strong excitation, more or less of the free energy may be degraded into heat before appearing as mechanical potential energy in the muscle."

For our present purpose (as well as for other purposes) there is a whole lot of thought-food in a chance report like this, for it suggests how entirely arbitrary, as a matter of denotative and descriptive words only, the various concepts of varieties of energy at present are—how perfectly integrated and unified and almost identified they must be in fact in the actual nature. And even then the dominant aspect of bodily energy, namely, the actuating (or inhibiting?) kinetic strains in the motor neurones, are only alluded to casually (*e.g.* "strong excitation") although of the living normal neuromuscular mechanism they must constitute a most essential factor, and through them the whole volitional phase of energies is involved in the actual motor event.

In an appendix to this same article Hill discusses this germane topic of free energy in relation to physiologic problems. This goes so directly to the heart of our present topic that it is expedient to quote it almost entire, thus: J. Bäron and M. Polànyi (*Biochem. Ztschr.*, liii., p. 1, 1913), "assuming the truth of various hypotheses made by Nernst, find that the free energy of the oxidation of glucose at 37° C. is some fourteen per cent. greater than the total energy of that oxidation; in other words this reaction can conceivably be made to give up not only 100 per cent. of its energy as mechanical work, but actually to acquire some of the heat energy of the surroundings and turn this also into work. In the same way they show that the free energy developed in the oxidation of fat is 106 per cent. of the total energy, and in the oxidation of protein 107 per cent. Whether Nernst's assumptions and figures are exact or not it seems probable that the free energy of all food stuffs is at any rate very high, that the plant stores free energy from the sunlight in a very concentrated form and is

not primarily concerned at all with the storing of total energy. In nearly all living things the manifestations of life, growth, electrical and osmotic phenomena require solely a supply of free energy; total energy, that is, practically total heat production, except in the case of the wasteful and highly differentiated warm-blooded animal, is only incidental. The bodies stored by plants under the influence of the free energy of the sunlight, and used by them and by animals for showing the phenomena of life, are capable if suitably employed of having absolutely all their energy turned into mechanical, electrical or osmotic energy, and are capable apparently even of taking up a certain amount of the heat energy of their surroundings and turning it into work. This being so, it is not very astonishing that under some conditions the muscle can provide mechanical potential energy with an efficiency of 91 per cent. from a partial breakdown. The possibility of an efficiency of 114 per cent. is present in the existence of the reaction whereby glucose is oxidized to CO_2 and water; and in the living muscle the efficiency of the whole process (*i.e.* counting the recovery oxidative process) never seems to rise beyond 50 per cent. The voluntary muscle, therefore, seems to have at the most an efficiency of only about one-half of what is theoretically possible in the break down of the ordinary food stuffs. Possibly other tissues, slow unstriped muscles, glands, the kidney, the electrical organs, etc., in which the velocity of response is less, may have an efficiency in delivering up free energy more nearly approximating to the theoretical maximum; in some organs efficiency may not be sacrificed to quickness of response, for it is well known that the theoretically reversible, and therefore most efficient machine, is one in which the reaction proceeds almost infinitely slowly. The striped muscle has hitherto proved the best material on which to investigate the "efficiency," *i.e.* the relation of free energy delivered to total energy, attained by living things. Other forms of free energy, osmotical and electrical, are, however, available for this comparison, as well as the mechanical energy provided by unstriped muscles; and results of the most intense interest may possibly be acquired by a study of the free energy delivered by living organs and organisms of all kinds, as well as by an investigation of the process in which all this free energy is obtained by the green plant from the sunlight."

It is important to notice the considerable number of forms of energy mentioned in this note and to observe the readiness with which (it is assumed as a commonplace acceptable by all) they transmute into each other.

An article by H. S. Williams, M. D., in *Harper's Magazine* for June, 1913, summarizes recent "naïve speculation" concerning the interrelations of energy and matter in a way to drive home this confusing concept: . . . . .

"This dissection of the ray of radiant energy was made, as we have seen, with the aid of the spectroscope. It is obvious, however, that an ordinary beam of light, before it is split up by a prism, must contain the entire series of waves of energy—heat-waves, light-waves, and ultra-violet waves—blended and intermingled. We have just seen that different portions of these waves may be tested by the thermometer (or by its more delicate counterpart, the bolometer), by the eye with or without the aid of the spectroscope, and by the photographic plate.

"But there is a joint effect of the waves of radiant energy which may be interpreted in terms neither of heat, light, nor photographic effect, but in terms of physical pressure.

"The exquisitely delicate instrument which measures this effect is called the radiometer. It was devised by two American physicists, Professors E. F. Nichols and G. F. Hull, and it is in effect a more delicate modification of an apparatus first made by the English physicist Sir William Crookes. The little instrument demonstrates that the waves in the ether, which are interpreted as heat or light or electromagnetism, and which are rushing through space at the speed of 186,000 miles per second, wash against any object that lies in their path with an actual pressure—manifesting themselves as a positive push, in addition to their other effects.

"This is quite what one might expect, perhaps, were it not that the ether is so exceedingly intangible an entity—one dare not say substance. Clerk-Maxwell, the most famous student of the ether, did indeed declare, from theoretical considerations, that this push must take place. But between theory and demonstration there may be a wide gap, and it remained for the experiments of Professor Lebedew in Europe and of Professors Nichols and Hull in America, undertaken simultaneously but quite independently, to place the matter beyond dispute. Now we know that every ray of sunlight gives a positive push to any material substance it reaches, and that a similar push accompanies all other radiations. And as every body not at the absolute zero of temperature—a degree of cold never yet attained in a terrestrial laboratory, and obtaining, if anywhere, only in the depths of stellar space—is giving off radiations, it follows that all bodies are pushing and tending to repel all other bodies that their radiations can reach. . . . .

"Meantime, the proof, that this radiant push exists and is everywhere operative, is in the highest degree interesting and important. For an ether wave, that pushes with such force against anything with which it comes in contact, must be a factor in the distribution throughout the universe not only of energy but of matter. Professor Svante Arrhenius, the famous Swedish physicist, has estimated the size of a particle of matter which would be driven before the light-waves, as particles of dust are driven before the wind. He believes that radiation pressure explains the phenomena of the comet's tail, of the sun's corona, and of the aurora borealis, the latter being due to the activities of electrified particles driven to the earth from the sun. Thus radiation is in a sense a counter-force to gravitation.

"What gives the phenomenon chief interest from the present standpoint, however, is that it shows the tremendous energy of the atomic forces that send out the ether waves. A molecule or atom vibrating in such a way as to send off—at the rate of many billions per second, and at a speed of 186,000 miles per second—waves powerful enough to drive relatively large particles of matter before them must be in itself a center of energy of astounding power, notwithstanding the incomprehensible minuteness of its size.

"All these studies of the different manifestations of energy point in the direction of the atom, and give us more or less vague estimates of the activities of its tiny structure. It remained for a new line of investigation to reveal the atom itself. The new observations came about through the discovery of substances having curious properties hitherto unsuspected but now familiar to every one under the name of radioactivity.

"The initial discovery of a radioactive substance was made by the French physicist Becquerel, through the accidental observation of the effect of the chemical called uranium on a photographic plate. The discovery of other radioactive substances, including radium, by Professor and Madame Curie, quickly followed, and the strange new properties were studied by many workers, chief among whom is Professor Ernest Rutherford, now of Manchester University.

"The essential phenomenon of radioactivity consists in the giving off of rays capable of affecting the photographic plate and of penetrating opaque substances. The radiation comprises at least three different types of rays, which have been named alpha, beta, and gamma rays. It is now known that the alpha rays consist of relatively heavy particles which

are in reality atoms of helium, each carrying a double charge of positive electricity. The beta ray is identical with the cathode ray, which develops when electricity is passed through a Crookes or vacuum tube. The gamma ray is identical with the *x*-ray, which is developed when a cathode ray strikes the walls of the glass receptacle. It is due to the impingement of beta rays on the particles of the radioactive substance itself, and it probably constitutes a pulsation in the ether of a kind analogous to the waves of light and electromagnetism. But its precise nature is not very clearly understood.

"The alpha ray has been studied with great care, and it has given up one secret after another. That the alpha particle is an atom of helium is a startling fact. For helium is an *element*, hitherto known as an inert constituent of the atmosphere. And to suppose that one element can be transformed into another is to suggest a restoration of the obsolete heresy of the alchemist. Nevertheless the demonstration is complete that the alpha ray does consist of helium atoms, and that it is precisely the same whether it emanates from thorium, from radium, or from any other known radioactive substance—however the fact may be explained. . . . .

"Already it has been shown that even an elementary gas may consist of a mixture of a great many different substances. In the case of oxygen, the photographs reveal no fewer than eight different forms of atoms and molecules, ranging from individual neutral atoms of oxygen to molecules composed of six atoms with a positive charge of electricity. Thus the physicist not only photographs the atoms, but records their intimate transformations and combinations.

"We have seen that the atoms which thus give up their secrets to the photographic plate are billions of times smaller than the smallest particle of matter that is directly visible under the microscope. It would seem, then, as if this recent feat of Sir Joseph Thomson, together with the spectacular demonstrations of Professor Rutherford, must carry us into the realm of the invisible almost to the limits of imaginable minuteness. But, in point of fact, there remains one other step that the physical investigators of our time have been able to take, which would still further tax credulity were it not certain that the things recorded are the results of definite experimentation and not of mere day-dreaming.

"The final feat of analysis to which I now refer is that which demonstrates that within the smallest atom there is a *something* almost two thousand times smaller than the atom itself—a something that is detachable from the atom, and susceptible of being measured as to its mass and tested as to its electric charge with the aid of apparatus actually in use in the laboratory. This ultimate particle of matter is called the electric corpuscle or electron. We owe our knowledge of it chiefly to Sir Joseph Thomson. It is the smallest thing in the world; and it is probably the basal substance out of which all matter of whatever character is built. Our present view of it must be confined to a brief reference to the manner in which it has been weighed and measured.

"The electron was first revealed in the cathode ray, which, as we have seen, is generated in a vacuum tube when electricity passes through it. The cathode ray, as such, consists of a stream of electrons driven off from the negative pole or cathode. The fact that these particles are deflected by an electric current shows that they are tangible substances, and the amount of deflection with a given current makes it possible to compute the charge of electricity they carry.

"The electron appears again as the constituent of the so-called beta ray given off by a radioactive substance. Electrons may also be liberated from ordinary matter when any substance is heated to a very high degree, or when rays of ultra-violet light impinge on a metal at ordinary temperature. Yet, again, they appear in ordinary gases when a heavy charge of electricity is forced through the gas—say, a lightning-stroke. They are likewise liberated in a gas subjected to the *x*-ray or to the so-called gamma ray of radium. . . . .

"As we penetrate thus far and farther into the realm of the infinitely little, seeing in imagination the smallest visible particle of matter resolved into myriads of molecules, each molecule into sundry atoms, and each atom into its teeming swarms of electrons, the question naturally arises, What lies beyond?

"The answer is, that, so far as present-day science knows, the electron is the last term of the series. Since the mind cannot grasp the conception of empty space, physicists imagine an all-pervading ether, permeating everywhere between the particles of matter, and serving as the medium of communication whereby energy is transmitted from one particle of matter to another throughout the universe. Light, electricity, magnetism, radiant heat, are various manifestations of energy transmitted, as it is believed, in the form of waves in the ether.

"This ether, as the physicist conceives it, has neither weight nor discrete substance. It is the unique, all-pervading something that is neither energy nor matter. Its importance from a human standpoint may be summarized in the statement that but for the ether neither light nor heat would come to us from the sun. When we reflect that the ether is supposed to penetrate everywhere between the particles of matter, and that material substances, so far as experiment goes, move through the ether without being in the remotest degree obstructed, it will be obvious that this all-pervading medium is an ever-present mystery. It has been a puzzle to surmise how the particles of matter could produce waves in a medium which seemed in no wise to obstruct the activities of these particles.

"But now it appears that the link between the structureless ether and matter, with its atomic structure, is found in the electron. This infinitesimal particle grips the ether somewhat as material substances grip the air, and its activities set up waves in the ether which are as tangible as the waves that radiate out from a pebble dropped into the smooth surface of a pond.

"The ether-waves set up by the electron vary in length or degree of agitation. But they move through space at a uniform rate of speed which has been demonstrated to be about 186,000 miles per second. Waves of a certain degree of agitation we interpret as heat; waves of another order we interpret as light—red light, or green or yellow or blue or violet, according as the waves are longer or shorter. Still shorter waves produce ultra-violet light, which affects the photographic plate, but is invisible to the eye. Waves of yet another order constitute electromagnetic currents, such as are used in wireless telegraphy.

"But, according to the view of present-day physics, no one of these sets of waves would agitate the ether were it not for the activities of the electrons, which, grouped in various fashions, are hurtling hither and thither within the structure of every atom of matter, or are dashing at breakneck speed from one atom to another.

"Some imaginative physicists think of the electrons as making up planetary systems within the atom, and as circling about with infinite speeds in orbits differing only in their infinitesimal smallness from the orbits of planets and stars of the visible universe. Other physicists caution us against drawing too close analogies between the stellar and atomic systems. But all are agreed that the activities of the electron, whether thought of as orbital or as vibratory, are enormous. Sir Joseph Thomson estimates that an electron once dislodged from its atomic system may dash hither and thither from one atom to another at such speed as to change its location forty million times in a second.

"Be that as it may, the demonstration seems complete that the activities of the electron, and these alone, produce the manifestations of energy which we interpret as light, radiant heat, and electricity. All chemical action is likewise held to be due to the activities of the electron. It is suspected that gravitation is of the same origin.

"The electron which thus seems to be responsible for all manifestations of energy is regarded by many physicists as the sole constituent of matter. Different kinds of atoms, in this view, differ from one another only in the varying number or diverse arrangement of their component electrons. It seems well within bounds, therefore, to say that this inconceivably minute particle, which is far and away the smallest thing of which present-day science has any knowledge, is at the same time far and away the most important thing in the universe."

W. W. Strong takes another step into recent speculation in this direction, enlarging yet further, somewhat, the range of the perfect unification of things, thus: "Is there a penetrating radiation in space? Do the stars, the sun, the moon, etc., emit a penetrating radiation? It is quite probable that they do—especially those bodies such as the moon, that possess little, if any, atmosphere. It is doubtful, however, if any such radiation can penetrate our atmosphere, it being equivalent in absorbing power to thirty centimeters of mercury. If the radiation was more highly penetrating it could easily pass through tour atmosphere. Up to the present time no evidence of any cosmical penetrating radiation has been obtained.

"If it were possible to focus the gamma radiation and to transmit parallel beams of it, and if radium was not so expensive, it might be used as a means of signalling. Imagine a prisoner in a cell with a small quantity of radium. He moves this back and forth in front of his window so that at one time the gamma rays are cut off by the wall while at other times the rays pass on to the outside. His motion is made to correspond to the dots and dashes of a Morse telegraph code. A man at a distance has an ionization chamber connected to a galvanometer and the galvanometer needle records the dots and dashes. This constitutes probably the simplest possible form of wireless apparatus.

"Another question, do the radium and thorium emanations in the air, the active deposit or the penetrating radiation either directly or indirectly affect our health? Does it affect the growth of plants? At the present time no definite answer can be given but the writer has thought that such effects existed, especially as regards the growth of plants. The existence of the emanations and of the active deposit certainly affects the ionization of the air very greatly in the neighborhood of plants and this affects the potential gradient. The potential gradient should have a very pronounced influence upon the flow of the sap.

"In the early days of radioactivity it was suggested that there was either a penetrating radiation or a kind of pervading energy that the disintegrating radioactive atoms could transmute into kinetic energy. It may be that there is a penetrating radiation coming from space that penetrates the upper ten or twenty kilometers of the earth's surface and causes the thorium and uranium radioactivity. The generally accepted belief to-day is that the cause of radioactivity depends upon the structure of the atom itself. The quantitative relations between the atomic constants, the decay constant and the initial velocity of the alpha particles of the different radioactive elements supports the latter view. Swinne finds that the difference between the initial velocity of an alpha radiator of one family and the corresponding element of another family is nearly a constant. On the other hand, it may be these properties of certain atoms that gives them the power of absorbing outside energy. If there is such a very penetrating radiation and its intensity showed periods of maxima and minima, the amount of heat generated by radioactive processes would fluctuate. These fluctuations might aid in the explanation of the glacial epochs. . . . .

"Geologists have usually claimed that the earth has been cooling during the past and that at one time it was a molten mass. These conclusions were inevitable as long as there was no source of heat in the earth. Since radioactive matter is evolving heat continually, it follows that its existence in the rocks furnishes a source of heat and if it generates heat more rapidly than the rocks conduct it to the surface, the temperature must rise. Assuming that the rocks of the earth possess the radioactive content as determined by Strutt, Eve, and others, it follows that a thickness of about thirty miles of the radioactive bearing rock would generate the heat which is being lost by conduction and radiation. If radioactive matter is distributed in the same way throughout the earth, two conclusions follow—either the earth is getting hotter or radioactive processes are different under these conditions from what they are in the laboratory. Up to the present no one has been able to affect in any way the velocity of radioactive transformation, either by the action of high pressure or by high temperatures.

"In the radioactivity of uranium and thorium we see the disintegration of complex atoms into simpler atoms with the liberation of comparatively enormous quantities of energy. Does the reverse process take place? Is there an evolution of the elements?

"In seeking an answer for this question we must consider two worlds, the intraatomic world and the extraatomic worlds. What are the processes and the laws that govern the internal mechanism of atoms? Is there such a thing as an intraatomic temperature determined by the average kinetic energy of its parts? What are the means of conveying energy into and out of the atom?

"Our extraatomic world consists of the motions of molecules and atoms. Temperature is a measure of the amount of this motion. We, on the earth, are fairly well familiar with a range of temperature extending from absolute zero to say 2,000° C. The upper limit of temperature velocities is given by the velocity of light. No electron and hence no molecule can move with any greater velocity. But before such velocities are reached electrons and even other atoms begin to move "through each other" (*e.g.* the alpha particles). We no longer have ordinary molecular collisions. Thus when the temperature becomes sufficiently high the relations between the phenomena of the intraatomic and extraatomic worlds become very intimate. Our world is one of great inanition compared with a world at 2,000° C. A world at 2,000° is one of comparative rest compared with a world at a temperature of 200,000° or higher, one where the average kinetic energy of atoms is equal to that of an electron moving with a velocity almost equal to that of light. It is in this latter temperature region, that things really become interesting and it is probably under these conditions, that atoms are born. If there is an evolution of the elements it must be expected under these conditions. At our ordinary temperatures the intraatomic world is surrounded by an almost perfect refrigerator—there is practically no relation with the outside world at all.

"Recently quite a number of interesting papers have appeared which indicate that matter may be much more complex than we consider it to be and that all the elementary atoms are closely related through their origin by radioactive evolution. Soddy and others consider that many of the elements are practically identical from a chemical point of view. Among these groups are Ur X, radioactinium and thorium; mesothorium and actinium; Th B, lead and possibly Ra B and Ac B; and probably Th C, Ra C, Ac C, and bismuth. According to Fajani the expul-

sion of an alpha particle moves an element two places to the left in the periodic system, while the expulsion of a beta particle moves the element one place to the right without changing the atomic weight. Following this rule the radioactive products can all be placed in the periodic system. That this can be done is a very strong indication that every element originated by a process of radioactive disintegration such as takes place in the thorium and radium families.

"At the present time the only evidence of the evolution of the atoms is to be found in a study of the nebulæ and the stars. The highly attenuated nebulæ contain only a few elements, mostly helium and hydrogen. Apparently as these nebulæ condense and grow older, carbon, silicon, magnesium, calcium, and iron appear. Apparently sodium does not appear until later and the nitrogen family is often absent (as it is in the sun). Just how the elements can grow is entirely speculative, though one would expect the combination of the elements to be the inverse of the disintegration process. In this connection it is interesting to mention Nicholson's process of building all the elements out of four protyles: coronium, 0.5131; hydrogen, 1.008; nebullium, 1.6277, and protofluorine, 2.3604. It is very remarkable that many of the atomic weights can be made to be an almost exact multiple of integral multiples of one or more of the above protyles. According to this view, radium is a compound as follows: $8(He_3Nu_3Pf_2H_2)$ $2(He_2Pf_3H_3)$-He_3" ("*Radium*").

But, just as inevitably as before, surges the eternal question of the ages, What lies beyond? Not in space, this time, but in reality, in imagination, in terms of the best human reason, eager for ultimate truth, *What* lies beyond this ether and these electrons, producers of the manifestations of energy, interpreted as light and radiant heat, and electricity, and chemical action, and gravitation, and muscular force, and the "free energy" of muscle, and the nervous impulse, and mechanic energy of every phase? Does nothing lie beyond? Are these electrons real? Can one's imagination, one's thought, the speculations of the physicist eager for truth go thus far into infinite division and stop, content? "But what go ye forth for to see?" Something, we may be sure, no human eye will ever see, the electron; all right as the present limit of physical speculation were not one actually compelled to ask, What lies beyond?

Some considerations tend when taken together to deprive the nervous system of its pre-eminence as the representative of consciousness in animals, a supposition which naturally arose from the former's peculiar function of being the chief means of associating impulses passing between the really active tissues of the body and between their parts. On the other hand, certain events in the realm of chemiphysics have recently altered somewhat our view of matter itself and this alteration bears in a sense on the basal relations or unity perhaps of mind and body. Matter is proven in certain cases at least to be not something fixed and immutable but rather centers of spontaneous forces active despite all known conditions, and the tendency is undoubtedly to place force where formerly matter stood. In biology the same tendency has long been felt, for it is seen that those reactions we summarily call vital are indiscriminately composed of heat, movement, electricity, light, etc. But now that similar phenomena are seen to take place in inorganic substances as well as in protoplasm, it is obvious that little is left of the "substantial" part of matter. Just as a limited and rationally forced panpsychism is in the philosophical air, so this panenergism or pan-kineticism (if I may be pardoned the rude terms) is in the physical air. To the one view (the substantial rational seeing of idealism) nervous processes as well as mental processes are psychical and the body itself is sentient experience. To the becoming physical view, matter is something akin to a vortex of kinetic energies and the brain, in the last analysis, becomes reduced to the powers of chemiphysical attraction and repulsion, of heat, of electricity, of light, of chemism, modes of movement. Both to physics and to epistemology protoplasm is a somewhat whose chief characteristics are movement, change, indescribable because unique but identical in terms of consciousness. Deny it as one may with wealth of dialectic, with statement heard so often that "force and movement are not consciousness but force and movement," still consciousness does seem more like these various forces to which protoplasm bids fair to be reduced by physics than like the lumps of white and grayish matter from out the interior of a bony skull, and to this extent the becoming view of physics and the liberal view of consciousness approach each other. If consciousness is not a force still it has some of the qualities of force as we know it—and no matter what force is as we don't know it! Is this heresy to orthodox idealism, to claim the forces of protoplasm and the thing we call consciousness alike in some respects and to base on this similarity an increased claim for the wider locus of consciousness? At any rate, the sole contention is that the becoming conception of protoplasm including nerve as made up of molecules or of clusters of molecules which are, even physically, reducible to centers of chemic force, makes it somewhat easier to conceive of some sort of correspondence between consciousness in animals and the mechanism of their life. The difficulty is not to see this this way but rather to persist in spite of basal resemblances in maintaining a contrast based alone on a logical syllogism. Above, we urged the usefulness of this very syllogism at the basis of idealism—at present we urge its limitations when the basal paradox of our experience demands that we should do so. A few years ago most physicists would have claimed the doctrine of the conservation of energy infallible in our experience; to-day he may see hints of phenomena which relegate it perhaps to the limbo of other tottering theatrical idols! If simple metals exhibit phenomena of this sort, surely we may expect from a substance as highly elaborated as living protoplasm relations at least as aberrant from the supposed laws of matter. And protoplasm finds only one of its forms, and that apparently not the most active chemically, in the protoplasm of the nervous system.

The structure of protoplasm, of late gradually made out conjecturally at least, offers a pre-eminently appropriate and adequate seat or representative for consciousness—its uniqueness and the uniqueness of sentient experience correspond. Let us glance at some of what are probably the salient features of this substance bioplasm, biogen, or protoplasm, "life-stuff," "life-bearer," "primal matter." Each year enlarges our knowledge of it as obtained through the microscope, and continually its general chemiphysical nature becomes better known. Into the theories of its morphology we need not go, for surely it is its basal chemic constitution and not its physical structure which underlie its relations to consciousness. If biochemistry has learned anything surely about the structure of biogen it is that the group or cluster corresponding to the molecule of inorganic matter is of unique complexity and of a maximum instability. Among the constituents of this substance and probably of every cluster composing it are three materials organic in nature and each of great complexity. These three, of course, are proteid, fat, and carbohydrate, and proteid constitutes nearly the whole. Besides these, there are water and an unknown number and variety, very large, of salts which elsewhere are termed "inorganic," here doubtless part of the biomolecule, or life-unit. Of these five classes of constituents of this vital unit every one is a compound and three at least of them of great complexity, especially so the protein. No two analyses of the many forms of this substance are alike and no one at all represents

the original substance, for chemical analysis inevitably kills it and its structure chemically depends on its life. There is no doubt that all of the proteins contain hundreds of "atoms" in their units and many of them thousands. To account for the spatial arrangement of these thousands of atoms the imagination must be actively employed, but the problem is simplified by considering the "atoms" stresses and strains, forces, rather than as space-filling material bodies. The fats of the vital molecule and the carbohydrates are also complicated in molecular structure with scores of "atoms," and in instability only secondary to the proteids, while the inorganic salts form combinations with these in the life-unit group which are quite unknown. All of these "atoms" are continually interchanging as the vital unit anabolizes or catabolizes, and not only interchanging with themselves but with other more or less similar complexes brought to them as food. Of all the "molecules" known to chemistry, this one, probably, at the basis of protoplasm and of life is the most complex in its ever-changing construction and probably has as its essence a metabolism quite unique. This metabolism, these most intricate chemical interactions within and between these vital clusters making up protoplasm, can be occasionally *imagined* by the chemist, who knows the nature of chemical reactions generally and the materials and end-products of these vital processes, but they cannot be described by him. From them are set free motion, heat, light, electricity, power of various sorts, phenomena we call forces. Nowhere else than in the living tissues of animals are the causal or the effected conditions so complex and interinvolved, and above all so capable of permanent adjustment to varying relations. Such a uniqueness is fit concomitant for the uniqueness of consciousness. This intricacy of forceful interaction would seem to supply the only apparent basis for the intricate phenomena of the mental process. On the one side a living body made up of events like these implied, almost too complicated to be even suggested by other than a biochemist—on the other side the indescribable experience consciousness. Only these two of all finite things are reasonably adequate, it may be, to represent each other mutually.

Here then in living matter, especially in ourselves as body and mind, energy and consciousness, we see the dim basis of the last answer to the problem which death alone perhaps will really solve: What lies beyond in the range of our thinking?

In the writer's humble opinion, everything that is commonly considered the ultimate essence of things, alive and changing in a world of change, lies beyond. To this view we must come if we would see the final fulness of "energy" and its present-day implications and meaning. We must let our mind bridge once for all the gap between matter (as protoplasm) and energy (as neurility) and consciousness, for here, along the nerves, this transition seems easiest. If we can go a step more and contrive to see, with Bergson, the essence of all this finally in duration, we have reached the present limit of analysis of answer as to what lies beyond—sentient duration, enduring sentiency, as one pleases to say it; conscious activity at any rate.

Nor may we stop *short* of this if we would have what seems a *real* answer to our inquiry as to the nature of energy. GEORGE V. N. DEARBORN.

Engadine, Upper.—The Upper Engadine valley extends from Maloja, at the summit of the pass, to a little beyond Samaden, in a direction from southwest to northeast. Through this valley runs the Inn, while high mountains belonging to the Bernina and Julier chains enclose it on either side. The Upper Engadine valley is wider than the lower and contains several lakes. It is about thirty miles in length, and varies from a half a mile to a mile in width; and its mean height above sea-level is 5,500 feet. The whole Engadine is one of the highest inhabited valleys in Europe. In the Upper Engadine are situated the health resorts of Maloja, St. Moritz, and Samaden, where consumptives go in the winter for the "air cure"; and Pontresina and others which are visited in the summer only.

The Upper Engadine valley is again divided into an upper and a lower portion, quite different in the character of their scenery. In the upper portion, extending from Maloja to St. Moritz, where are situated the lakes before-mentioned, the mountain boundaries on either side are grander and wilder and much loftier, and their summits are covered with extensive glaciers and snow fields. In the lower half, extending from St. Moritz to the termination of the valley, the picture is quite different. "Here there are no lakes, the floor of the valley is much wider, and is occupied by broad stretches of meadowland through which the Inn quietly and tamely flows along." "The mountains on each side are of lower elevation; they all rise in gentle slopes from the floor of the valley, and present no bold or striking features of form or outline."

The upper or southern end of the valley is open and affords a ready ingress to storms of wind and rain approaching the valley from the southwest; the wind, however, blows most in spring and summer, while the winter is the calmest season of the year.

Climate.—The climate of the Upper Engadine is very similar to that of the neighboring valley of Davos, already described. (Cf. *Davos.*) In the first place, there is the striking variability of the temperature as in all high-lying stations. The diurnal variations are sudden and great; for instance, in August, between seven and ten o'clock, the mercury rises from 44.6° to 53.6° F.; and again at sunset it falls as rapidly as in the morning it rose. Secondly, the great radiant heat of the sun is another characteristic; for instance, the maximum sun temperature in the upper Engadine on February 4, 1876, was 118° F.

The number of hours of possible sunshine in winter is somewhat greater in the Engadine than at Davos; for example, on January 1, the sun rises at Maloja at 9:35 and sets at 3:45, while at Davos it rises at 10:03 and sets at 3.

The average rainfall, most of it being snow, is 32.67 inches; it lies on the ground for over five months, beginning about November 14. The relative humidity is 75 per cent. The mean annual temperature is about 36.5° F., and for the seasons as follows: Winter, 18.1° F.; spring, 33.7° F.; summer, 50.9° F.; autumn, 36.5° F. There is said to be rather more cloudiness in the Upper Engadine than at Davos. As at Davos, the purity and exhilarating quality of the air in this region constitute, in brief, the great striking characteristic which all experience who enter this valley. The writer can never forget his own sensations as he came over the pass from Chiavenna into this delicious atmosphere. Merely to exist was a delight, and to spend the day in tramping over a glacier or mountain climbing was exquisite pleasure, and after such exertions no sign of weariness was experienced.

A considerable number of consumptives take the winter cure here, and there are excellent accommodations at Samaden, St. Moritz, and Maloja; at the latter is the large Kurhaus, accommodating five hundred guests and especially arranged for a winter residence; the ventilation and sanitary arrangements are of the best. In the village of St. Moritz is the great caravansary "Engadiner Kulm," with a wonderful view over the whole district of St. Moritz. Here one can find every comfort, and even luxury—large reception-rooms, a library, a dining-room for three hundred and fifty persons, and a fine collection of engravings and pictures. The English and Americans chiefly patronize this hotel. St. Moritz

is the highest village in the Engadine or in Switzerland, having an elevation of 6,085 feet.

A mile or two from St. Moritz village are the St. Moritz baths. These are supplied from two acidulous iron springs—the old and the new, containing soda with a large proportion of fixed solids and free carbonic acid. These waters are used both for drinking and for baths and are visited in the season—from the middle of June to the middle of September—by numerous patients of all nations. The conditions benefited by these waters are anemia, chlorosis, dyspepsia, menstrual irregularities, various derangements of the nervous system, etc. There is a large Kurhaus with many rooms, two bath houses containing eighty baths, and complete hydrotherapeutic arrangements (warm, cold and Scotch douches, sitz baths, vapor baths, etc.), as well as facilities for massage. There is a covered promenade leading from the Kurhaus to the spacious pump room of the new spring. There are generally about three hundred and eighty patients in the Kurhaus, and every attention is given to their comfort and diversion.

What has been said regarding the winter climate of Davos in the treatment of pulmonary tuberculosis applies equally to that of the Engadine; there is no material difference between the "air cure" of the Davos and that of the Engadine valley, and the results should closely resemble each other. In the winter resorts of the Upper Engadine there is greater variety of scenery and the life is more restful and quieter.

Regarding the uses of such a climate as that of the Upper Engadine for cases other than tuberculosis, a few words can properly be said here, applicable also, in a measure, to all high-altitude resorts. Whatever the malady or condition there should exist a "certain integrity and reactionary power of the constitution," if the patient is to be benefited by a climate which is stimulating and bracing, such as this. This being presupposed, we can say, in general, that where functional activity needs to be improved, and the whole system toned up, a few weeks' residence in this pure, clear, dry, bracing air will almost surely produce favorable results. "I believe," says Burney Yeo, "this kind of climate is especially useful to those who have been *strong*, but by some accident or other, such as overwork, or illness, or trouble, have become weak; to those who possess a latent power of reaction." To enumerate especial conditions, there may be mentioned, nervous dyspepsia, want of appetite, sleeplessness, malaria, neuralgia, anemia, the later stages of convalescence from severe illness, hypochondriasis, asthma uncomplicated with emphysema or organic disease of the heart or arteries, chronic bronchitis with much secretion, and those various mal-conditions arising from "insufficient exercise in the open air and deficient absorption of oxygen."

Burney Yeo happily expresses it when he says that much of the benefit that is derived from a short residence in an elevated region like that of the Upper Engadine is due to the alterative influence which it exercises on the human organism. "In passing," he continues, "from the sea-level to an elevation of over 6,000 feet we must alter in a very essential manner the conditions of our lives."

It is well also to bear in mind some of the contra-indications of a mountain climate like this. Such are, weakness from extremes in age; constitutional weakness; organic cardiac disease; atheroma; chronic bronchitis with dilated bronchi; and emphysema, muscular debility and general exhaustion, rheumatism, and inability to endure great and sudden changes of temperature.

Finally, if we are not in search of health or better health, we all need change occasionally—"that change which is the type of life and the condition of health; that change which is rest." Where can a more complete or a more refreshing change be found than among the grand glaciers and majestic mountain peaks of the Upper Engadine, where we can "draw in easier breath from larger air." EDWARD O. OTIS.

Enhydrina.—A genus of poisonous sea snakes in which the tail is flat. These reptiles are found in tropical seas. A. S. P.

Entamœba.—A genus of parasitic rhizopodous Protozoa, suborder *Gymnamœbina*, which is distinguished from *Amœba* by the fact that it is parasitic, and by the absence of a contractile vacuole. Several species have been found in the intestine, mouth, urinary bladder, lungs, and in abscesses and serous exudations. *E. coli* is a harmless commensal in the intestine; *E. histolytica* causes dysentery, abscesses, etc. See *Protozoa*. A. S. P

Enteralgia.—See *Colic*.

Enteritis.—An inflammation of the intestine, involving particularly the mucous membrane, and to a less extent the submucous layer. It may be either acute or chronic. The whole length of the intestine may be involved or, more usually, the inflammation is limited to certain portions of this.

The meaning of the term *enteritis* has varied considerably as used by different authors, and at different periods in medical literature. It does not appear to have been in use by the ancients. In the eighteenth century it was applied to the group of symptoms now included under peritonitis, although Cullen (1784) mentions two varieties of the disease, one of which evidently refers to an inflammation of the mucous membrane and subjacent tissues of the intestine. In France, at about the end of the eighteenth century, Pinel limited the use of the word to an inflammation of the intestinal mucous membrane. Its meaning was further restricted during the first half of the nineteenth century by Broussais (1821), who applied it to an inflammation of the mucous membrane of the small intestine only, and gave the name colitis to a similar process in the colon. This restricted meaning is still retained by some but the term is more generally applied to inflammation of both the large and small intestine.

At the beginning of the last century the lesions of the intestinal lymphoid structures found in typhoid fever were included under the general term enteritis, and this use of the term was continued to some extent even after the specific nature of the lesions had been demonstrated. At present the term is avoided by some authors, "intestinal catarrh" being used instead as indicating the character of the most frequent form of inflammation of both the large and the small intestines. As the same etiological factors may produce similar changes in both the large and the small bowel, and usually each is involved to a greater or lesser extent in both the acute and the chronic catarrhs of the intestine, and as it is often impossible to determine just what part of the bowel is involved the term enteritis will be used in this article as applying alike to inflammation of the small and large intestines, and hence synonymous with the term enterocolitis, while the terms ileitis, duodenitis, colitis, etc., will be used as applying to inflammation of the respective divisions of the intestine.

The summer diarrheas of children will not be discussed here, nor will the specific infections of the intestine, as these topics are treated elsewhere.

The catarrhal variety of enteritis is by far the most common, and for this reason the most important, and is by many authors the only form of inflammation included under enteritis. Both the acute and the chronic forms of this will be discussed at some length.

ACUTE CATARRHAL ENTERITIS.—Catarrhal, as here used, has the common meaning of the term, that is,

as indicating an inflammation of a mucous membrane characterized by a free exudation from the surface, usually rich in mucus. During life such an inflammation is evidenced by the presence of the inflammatory exudate which is discharged from the body, as well as by various other symptoms which are explained by the process.

Etiology.—The causes of acute catarrhal enteritis are most numerous. They may act as predisposing to, or direct excitants of, the inflammatory process. The dividing line between these two classes is frequently difficult to determine. The disease of the intestine may occur alone, or it may accompany or result from various other disorders. The intestine is particularly liable to be affected by any kind of irritating substances which are ingested, unless these are rendered harmless in the stomach, as well as by certain excretory products which pass through its walls; and of prime importance among the predisposing factors is the ease and frequency with which an abnormal condition of the blood supply of the intestinal wall occurs, in part due to some obstruction to the returning blood in the portal system, and in part to the lack of sufficient support for the blood-vessel walls by the surrounding tissue.

An unsuitable dietary is probably the most frequent direct cause of intestinal derangement. This may be at fault only in quantity, or in quality, or in both. Food which is entirely wholesome may, when eaten in too great quantities and particularly when only partially masticated, excite a diarrhea, as may also unripe fruit, uncooked vegetables, etc. This may be only an evidence of increased peristalsis, but often there is a true catarrhal inflammation of the intestine. The undigested food here may act as a mechanical irritant, but, of greater importance, it furnishes favorable conditions for abnormal bacterial development in the intestinal canal. This microbic growth evidently gives rise to a variety of active irritants. Also at times foods before being eaten have already undergone bacterial decomposition and contain poisonous products resulting from this. Such are tainted meat and fish, occasionally milk and its various products, etc. At times the inflammation can be explained as due to some idiosyncrasy. Thus lobsters, cheese, eggs, etc., when entirely wholesome and in moderate quantities, may in certain individuals give rise to an acute enteritis. Foul water also frequently produces a similar disturbance.

Among the active poisons whose entrance into the alimentary canal is followed by severe inflammatory processes are included arsenic, corrosive sublimate, antimony, the mineral acids, and caustic alkalies. The drastic purgatives, as croton oil, colocynth, elaterium, etc., in unsuitable doses may produce enteritis.

Exposure to cold, particularly a sudden chilling of the body after overheating, is a recognized cause of the disease. In what way this acts, whether reflexly through the nervous system, as seems probable, or otherwise, is a question; but some disturbance of the intestinal function is produced sufficient to excite an inflammatory process. Cold drinks, ice, ice-cream, etc., when taken in immoderate amounts, may have a similar result.

Excessive summer heat is also a common cause of catarrhal enteritis, particularly in young children; hence the popular term "summer complaint" so frequently applied to this. Its action is largely an indirect one, furnishing favorable conditions for bacterial growth in food before its consumption. Extensive burns of the skin may give rise to an inflammation and ulceration of the duodenum. The actual exciting agent here is probably a toxic substance which is formed at the site of the burn, and is excreted into the upper portion of the intestine.

The rôle of bacteria in producing decomposition products in various articles of food has already been referred to. No specific microorganism can be accepted as the usual cause of enteritis. In fact, the part played in the production of inflammation by bacteria growing in the intestine is so complex and as yet so imperfectly understood as not to warrant any considerable discussion. In brief, it can be stated that different members of the colon-typhoid group, including the so-called enteritidis group, are factors in this. Also that streptococci and the various intestinal anaërobes play a part. They may do this by direct action upon the mucous membrane, which is probably infrequent, or by chemical products of their growth in the intestinal contents. That bacteria play an important part in the production of enteritis appears beyond question.

Traumatic causes, such as blows on the abdomen, may give rise to intestinal inflammation. Gallstones may mechanically produce it, as can also the presence of certain intestinal worms.

Among the more important predisposing causes is age. Young children show but slight resistance to intestinal irritants, so that even cow's milk may be sufficient to produce a catarrhal enteritis in an infant. Old and debilitated persons have an increased intestinal susceptibility, and chronic congestion of the intestinal wall predisposes to the disease. Previous attacks of inflammation usually render the mucous membrane very susceptible for a time to slight irritation.

Pathology.—An external examination of the intestines may show them to be considerably distended with an accumulation of gas in the canal, or in severer cases, with early fatal termination, there may be a lessening of the intestinal lumen due to muscular contraction. The color, as seen from the serous surface, depends upon that of the contents of the intestines and upon the vascularity of the walls. It may be pale when the intestine is distended, red in spots corresponding to areas of congestion of the mucous membrane, yellowish due to bile, or dark red when blood pigment is included in the intestinal contents.

The appearance of the mucous membrane may vary much from what the severity of the disease would suggest. At times neither redness, nor swelling, nor increased secretion may be found postmortem, even when during life the symptoms of intestinal catarrh were marked. It is not usual to find the whole length of the intestine uniformly involved, though this may occasionally be seen in the secondary enteritis of infectious diseases, as scarlet fever and measles. It is more common to find portions of apparently normal mucous membrane separating the inflamed areas, which may be from only a few centimeters up to a meter or more in length. The inflammatory process may be confined to a single anatomical division of the intestine (hence a duodenitis, colitis, etc.) More often the colon together with the lower part of the ileum is involved.

The acute catarrh is usually characterized by hyperemia of the mucosa, either diffuse or localized, the latter being seen particularly in the vicinity of the lymph follicles and on the crests of the valvulæ conniventes. This congestion may be so great as to give rise to numerous punctate hemorrhages. The color varies from a bright red to purplish. But the entire wall may be gray, probably due to a postmortem disappearance of the hyperemia. The distention of the vessels in the more dependent loops of the intestines, due to a settling of the blood after death, is not to be mistaken for an inflammatory congestion. In rapidly fatal cases the hyperemia may be the only macroscopic evidence of inflammation. More commonly the mucous membrane is swollen, and on its surface there is a collection of a greater or lesser quantity of mucus, either in a uniform layer or in small masses. This may be quite translucent or opaque, the cloudiness being then due to the epithelial cells contained in the mucus; or it may be stained by the various substances in the intestinal

canal—yellow or greenish by bile, red or brown due to the presence of blood pigment, or dark from bismuth.

The active exudation on the part of the inflamed mucous membrane is indicated by the watery character of the intestinal contents. Here at times may also be found considerable masses of cast-off epithelial cells. To this condition the term *desquamative catarrh* has been applied. That this process is not entirely a postmortem one is shown by the presence in the colon of hollow, finger-shaped masses of epithelial cells which covered the villi of the small intestine. The valvulæ conniventes may be thickened and the villi swollen so that the latter can be seen more easily than they normally can. Not infrequently, in severe cases of enteritis, there occurs a localized superficial necrosis of the inflamed membrane, with resulting ulceration. These ulcers are at first small, rounded, flat, with walls that show but little infiltration, but they may gradually enlarge (catarrhal ulcers).

The lymphoid structures of the intestine are often enlarged, appearing as grayish projections with a hyperemic border. The solitary follicles may reach the size of a pin's head. At first they are somewhat translucent, the increase in size being then due to edema. As hyperplasia and cellular infiltration occur they become opaque. In the agminated glands the enlargement may be uniform over the entire patch, or only single follicles or groups of these are swollen. At times these changes in the lymphoid structures are very marked (follicular enteritis). The superficial portion of the follicles may become necrotic, and by a separation of this necrosed tissue there result small round ulcers, the so-called follicular ulcers. This follicular enlargement and ulceration are seen most frequently in children and may take place very rapidly. Such ulcers may increase in size and unite with neighboring ones to form irregularly shaped ulcerated areas, in the midst of which there remain small portions of mucous membrane. In the small intestine this process is most marked at the lower part of the ileum, although here it is usually less advanced than in the colon.

Microscopically there may be seen more or less edema and cellular infiltration of the mucous membrane. The distance between Lieberkühn's glands is frequently increased, and the epithelial cells lining these may show various forms of degeneration (mucoid, etc.). There may also be a marked proliferation of the endothelial cells of the lymph vessels. In the severer cases of acute catarrhal enteritis the submucous layer shows hyperemia with a cellular exudate around the vessels. The muscle coat is not involved in acute catarrh.

In the acute forms of enteritis there can be a complete recovery from the disease without leaving any permanent anatomical change. If ulceration occurred, small pigmented areas may indicate the sites of the healed ulcers.

Symptoms.—An attack of acute catarrhal enteritis usually begins suddenly, following directly upon the action of the exciting cause, the connection with which is often evident. There is at first a feeling of fulness and discomfort, soon amounting to actual pain, in the lower part of the abdomen. This pain, which is colicky or griping in nature, is quickly followed by diarrhea. After each evacuation there is a lessening or cessation of the abdominal pain which reappears before the next movement. The number and character of the stools are important in establishing the diagnosis, and in determining the extent and severity of the process. They usually vary from two or three daily, in the lighter cases, up to fifteen or twenty or even more in the severe attacks. If diarrhea is not present, as may happen when the small intestine alone is involved, the recognition of the catarrh becomes more difficult. In general the more the large intestine is involved the greater is the number of movements. The consistence of the first stool may be that of the normal feces, or it may be jelly-like. The subsequent ones rapidly become more liquid, gruel-like, and later watery, and are often frothy from the admixture of gas, the result of bacterial growth. The stools at first may give the usual fecal odor, but this soon changes, becoming more offensive. There may be a marked sour smell, particularly in milk-fed patients. Later, the watery discharges may become nearly odorless, but these if allowed to stand rapidly develop an offensive odor.

The color of the discharges depends largely upon the extent to which the small intestine is involved. When the upper portion of this takes part in the enteritis the stools vary from brown to light yellow from the presence of unchanged bile pigment; or, in children, but not in adults, they may be green from the oxidation of the pigment. The discharges may also be variously colored by articles of food, or by medicines (bismuth, iron, etc.), and by the presence of blood. The copious liquid stools may be nearly colorless. When there is a duodenitis, with catarrhal occlusion of the common bile duct, the feces may be very pale because of the absence of bile.

In normal feces mucus can be demonstrated only by chemical means. In enteritis it can almost always be demonstrated by macroscopic or microscopic examination. This may be in larger or smaller shreds, readily recognized, when the lower part of the large intestine is involved, or only in minute gelatinous particles intimately mixed with the stool. When the upper part of the colon and the small intestine are alone inflamed it may be unstained, colored yellow by the bile, or pigmented by the other intestinal contents. Epithelial cells, either fairly well preserved or showing various degrees of degeneration, are contained in the mucus. These may be present in sufficient numbers to give it an opaque appearance which macroscopically resembles pus, but pus cells are not often found in large numbers in the stools of acute catarrh. Blood, which is at times present in the stools in catarrhal enteritis in small quantities, indicates a marked inflammatory hyperemia or ulceration.

In the early stages of the disease remnants of undigested food are frequently passed per rectum, such as pieces of meat, particles of starchy foods, etc. When these bits of meat consist of connective tissue only they indicate a disturbance of the gastric function, but when muscle masses are found they are to be referred to a disturbance in the intestinal digestion. Such undigested food may occasionally be found even on the fourth or fifth day of the disease, having been retained in the bowel up to this time, and having served to excite the inflammation. Bacteria are usually present in the stools in large numbers. Prominent among these will be found the normal inhabitants of the intestinal canal, but at times streptococci may readily be seen.

Among the subjective symptoms the most prominent is the feeling of discomfort in the abdomen, with the colicky pains already referred to, which precede the evacuations. This sense of discomfort may be slight and may pass off in a few hours or a day or two, but in the severer cases the suffering may be so great as to produce a feeling of faintness, with coldness of the surface and sweating. There is a feeling of thirst, but all desire for food is lost. Only when the large intestine alone is inflamed may the appetite remain. Nausea may be present, at times accompanied by vomiting even when no lesion of the stomach can be found post mortem. There is always some feeling of debility and malaise, which in children or persons weakened in any way may amount to severe prostration.

The abdomen is often somewhat distended and is tender on pressure, either diffusely or in particular regions. Loud borborygmi, due to the presence of gas in the intestine, are frequently heard. Little of

value is obtained by percussion. Fever, is often not present in simple catarrhal enteritis, and when it does occur is slight in degree and passes off in a few days. On the other hand, the attack may be ushered in with a chill, followed by a pronounced rise in temperature, and a suspicion may be aroused that the case is one of typhoid fever. The spleen, however, is not usually enlarged, although Fischl describes this as of occasional occurrence.

The quantity of urine varies inversely to that of the watery stools. It may be but little changed from normal, but is frequently small in amount and concentrated. Temporary albuminuria with hyaline casts is occasionally present, and this even in the less severe cases, without fever or collapse. The casts may be found within a few hours after the beginning of the diarrhea. As a rule they disappear quickly as the catarrh improves. Jaundice is common when the duodenum is involved.

Such special symptoms as may occur in the secondary forms of enteritis belong rather to the primary disease and will not be discussed here.

The *diagnosis* is ordinarily made without difficulty. Some error in diet, exposure to cold, or other etiological factor is often evident. The acuteness of the onset, the gastrointestinal disturbance, the presence of mucus in the diarrheal stools, slight distention of the abdomen with diffuse or localized abdominal tenderness, and loud borborygmi, can hardly be mistaken for any other condition. The febrile cases may so closely simulate typhoid fever for the first few days that a Widal test of the blood may be necessary to eliminate this. In epidemics of cholera, the watery discharges of enteritis may so closely resemble those of the former disease that a bacteriological examination of the stools for the cholera spirillum may be necessary.

The determination of the particular portion of the intestine which is involved in the inflammatory process offers more difficulty and is to be determined largely by an examination of the feces. Still the localization of pain upon pressure when this is limited in area may be of significance. This is seen in the tenderness elicited along the course of the colon in catarrh of the large intestine, while in those unusual cases where the inflammation is limited to the small intestine pain upon pressure is found in the central portion of the abdomen and is absent at the sides. Duodenitis frequently accompanies a catarrhal gastritis, and the symptoms of the latter may completely obscure those of the former until the common bile duct becomes involved, when the resulting jaundice together with a dull pain on pressure in the right hypochondriac region indicates the condition of the duodenum. As previously noted, the upper part of the small intestine, or even its lower end when the colon is in normal condition, may be inflamed without an accompanying diarrhea. Yet here the feces give evidence of the condition. Mucus from the small intestine or from the upper portion of the large bowel is found intimately mixed with the feces, but not in masses of any size. The microscope may be needed to show its presence. Unusual quantities of undigested food, particularly muscle tissue, and the presence of unchanged bile pigment, are indications that the bowel above the ileocecal valve is at fault. In catarrh of the lower end of the large intestine the mucus is usually found in larger masses and less intimately mixed with the feces whether solid or liquid.

The *course* of the lighter forms of the disease is recovery in two or three days. In the severer types, or when the conditions for convalescence are unfavorable, this may occur only after several weeks. In adults the prognosis is generally good, but in young children and in the old or those otherwise debilitated, the disease is much more serious. After the patient appears to be entirely well there is frequently a marked susceptibility of the mucous membrane, so that slight irritants may again excite a catarrhal condition. A tendency to constipation may follow the acute diarrhea; it is due to a partial paralysis of the muscle layer of the intestine. This may develop into chronic constipation.

Treatment.—The treatment should be directed toward the removal of the exciting cause and the protection of the intestine against further injury. Frequently in the milder cases no medicinal treatment is necessary. The diarrhea has expelled the irritating substances which produced the catarrh, and a temporary withdrawal of all food, or the use of small quantities of liquid nourishment only, combined with rest, is quickly followed by recovery. When, however, the colicky pains persist and the abdomen becomes distended in spite of the frequent stools, a cathartic may well be given. For this purpose either calomel or castor oil is most often chosen; the proper dose for an adult being from two to five grains of the former, or a tablespoonful of the latter. Or the calomel may better be given in small doses repeated at short intervals, and followed by a Seidlitz powder. After the action of the purgative, and with a proper restriction of the diet and rest, the symptoms generally subside. When the pain is more intense this may often be relieved by the application of warm or hot fomentations to the abdomen. Opiates are occasionally required for this purpose. After the acute pain has been relieved, a flannel bandage around the abdomen is frequently of value in keeping this warm and so preventing a recurrence of the discomfort.

If the attack is of a more severe character, and accompanied by fever, there should be complete rest in bed for a few days. When after thorough evacuation has been accomplished the diarrhea persists, astringent and slightly antiseptic remedies may well be employed. The bismuth preparations are here particularly valuable. Salol in five-grain doses three or four times a day may often be given to advantage. Irrigation of the large intestine with physiological salt solution or with 0.5 per cent. solution of boric acid may be employed. Opium may be required in the more obstinate diarrheas. The tincture of opium may be prescribed in doses of from five to ten drops every three hours; or the opium may be combined with bismuth and chalk. Evidences of cardiac weakness are to be treated by the appropriate stimulants.

After the diarrhea disappears a tendency toward constipation not infrequently occurs. This is to be treated by enemata rather than by purgatives. Also in those cases in which diarrhea is absent from the first, when there is a history of the taking of indigestible food followed by colic and ineffectual straining at stool, a generous enema of warm water may well be given instead of a cathartic.

Regulation of the diet is of absolute importance both for cure and for prevention of a recurrence of the disease. Complete abstinence from food for the first day or two is advisable. As the appetite is usually lost this is easily accomplished. At this time such drinks as pure water, weak tea without sugar, or even small amounts of bouillon, or hot diluted milk, from which the cream has been removed, are in place. These should be given in small quantities at intervals. Very cold drinks and ice should not be employed. After this brief period of abstinence from food, the patient may be allowed to take thin soups of barley, rice, oatmeal, etc., or gruels made from the common prepared foods used for infants. For many, milk alone or diluted with barley or rice water is all that is required. Egg albumen, scraped raw beef, toasted bread or crackers, and later lamb chops, tender steaks, oysters, etc., are easily digested. Baked or mashed potatoes are to be allowed only after the diarrhea is completely stopped. Fruits and vegetables should be partaken of only spar-

ingly for some time after the attack, and for weeks the patient should avoid all kinds of indigestible food. The appetite usually returns with the disappearance of the symptoms. Otherwise stomachics may be employed. In secondary enteritis the treatment becomes largely that of the primary affection.

Chronic Catarrhal Enteritis.—*Etiology.*—The causes of chronic intestinal catarrh are largely those of the acute form of the disease. A severe acute attack of enteritis, when prolonged because of unfavorable conditions for recovery, may gradually pass into the chronic type. Or the repeated action of slight irritants, as indigestible food, alcohol, purgatives frequently employed, intestinal parasites, etc., may give rise to this condition. Here the process is at times evidenced by several acute attacks, or the symptoms of chronic enteritis constitute the first appearance of the disease. Anything which interferes with the normal circulation of the blood or lymph in the vessels of the intestinal wall tends to render it susceptible to inflammatory excitants. Thus cirrhosis of the liver and chronic diseases of the lungs and heart, which give rise to a continuous overdistention of the venous system, are very frequently associated with a chronic enteritis. Continual excretion of toxic substances through the intestinal wall, as occurs in chronic nephritis, and probably also in tuberculosis, malaria, and other diseases, favors a catarrhal inflammation. Overwork of all kinds, whether physical or mental, predisposes to the disease. Secondary forms of enteritis frequently follow various gastric disturbances, as well as intestinal tumors, displacements, and adhesions.

Pathology.—In chronic catarrhal enteritis the changes from normal which are found in the intestine are fully as varied as those of the acute form of the disease. In general the exudative processes here are less pronounced than the proliferative; the latter in turn, in long-standing cases, frequently being followed by atrophy of the affected mucosa. Also the deeper layers of the intestinal wall are involved to a greater extent than in the acute process.

The mucous membrane is at times found to be strikingly pale. This may be seen in autopsies upon small children who have died as a result of the disease. On the contrary, when a chronic congestion of the abdominal vessels has been prominent the color may be a dark red due to the hyperemia; or altered blood pigment may be deposited in the tissue in sufficient quantities to give it a slaty hue. The pigmentation here is most marked in the vicinity of the follicles and on the villi.

In chronic as in acute enteritis the whole length of the intestine is rarely involved, but areas of diseased and of normal mucous membrane alternate. The ileum, particularly in its lower portions, shows the characteristic changes more frequently than does the jejunum or the duodenum; but the processes in the large intestine are often more marked than those of any part of the small intestine.

The intestinal wall becomes thickened as a result of proliferative changes occurring in it. Both the mucous and submucous coats are involved, and the glandular as well as the connective-tissue elements take part in the process. The tubules of the glands elongate, become distended, and produce abnormal quantities of mucus which appears as a layer often quite adherent to the surface of the mucosa. At the same time the glands are somewhat separated by newly formed connective tissue. When the hyperplasia is circumscribed there may result polypoid projections of the thickened mucosa. This is more frequently seen in the colon than it is in the small intestine.

The subsequent changes that occur in the thickened wall are largely atrophic in nature. As the young connective tissue of the mucous and submucous coats gradually contracts, it compresses the glands of Lieberkühn, and as a result they undergo more or less atrophy. The villi likewise largely disappear so that the mucosa becomes thinned, and also smoother on the surface than normal.

The hyperplasia of the lymphoid tissue may be even more marked here than in acute enteritis; later, this too may atrophy, leaving behind smooth, darkly pigmented spots in place of the follicles. Here also are found both catarrhal and follicular ulcers. These gradually enlarge and become deeper. They may even extend to the serous layer, giving rise to a circumscribed chronic peritonitis by which adhesions between the different peritoneal surfaces are formed.

Complete recovery, in the anatomical sense, does not occur in chronic enteritis. An atrophy of the mucous membrane, smooth pigmented dots at the site of the follicles, scars resulting from healed ulcers, or some other structural evidences of the process still remain.

Symptoms.—Among the symptoms of chronic catarrhal enteritis the number and character of the stools again hold the chief place. Subjective symptoms may be entirely lacking except as they are connected with irregularity in the stools. Whereas in acute intestinal catarrh diarrhea is generally present, this does not hold true in the chronic form of the disease. Here the stools vary much. The classification of the cases, as given by Nothnagel, depending upon the frequency and nature of the discharges, will here be followed. This includes four groups. In the first one there is constipation, the stools being from two to four days apart and frequently occurring only after a laxative has been taken. This constipation is to be explained as due to a decreased automatic activity of the nervous apparatus, produced by the chronic catarrhal process. But with this lessened automatic activity there may be a normal or even increased susceptibility toward various irritants. The condition here is probably to be explained chiefly by a chronic catarrh of the large, rather than of the small, intestine.

The second class, which is larger, shows alternately constipation and diarrhea, and frequently these recur with noticeable regularity. The daily stools for two or three days will be very hard; during the following twenty-four hours there will be from four to six diarrheal discharges containing considerable mucus, and accompanied by a diffuse pain in the abdomen. Then constipation again follows. Or the stools may be normal for some days and then from four to seven diarrheal movements, with colicky pains, follow in one day, and this is succeeded by constipation. Here also constipation is the main feature, but the decomposition of the stagnant intestinal contents produces an increased peristalsis by acting upon the fairly irritable nervous apparatus. The periodicity of the constipation may be entirely irregular.

In the third class, which includes but few cases, there is a daily movement, but this is rather soft, not well formed.

The last group comprises those cases in which for months there may be daily frequent diarrheal discharges. In this class there is good evidence of disease of the small intestine as well as the large, furnished by the presence of unchanged bile pigment, or yellow-stained epithelial and round cells, in the stools. The condition is explained on the supposition that, because of the chronic enteritis, digestion does not proceed in a normal manner in the small intestine, and that the abnormal products (acids, etc.) formed here act in such a way as to irritate the inflamed mucous membrane of the large intestine and so keep up a marked peristalsis, causing the diarrhea.

There are still other cases in which, owing to some nervous influence, the evacuations may occur only at night time, or early in the morning.

Of the contents of the stools, mucus is most characteristic of the catarrhal condition. This varies

greatly in quantity, and may even rarely be absent in severe catarrhal conditions when the mucous membrane is atrophic. In general, its continued presence in the stools, whether these are firm or liquid, may be considered an indication of an existing catarrh.

The conditions of odor, color, and the presence of epithelial cells and of food particles are similar to those in acute catarrh. Blood, when present, gives evidence of an ulcerative process.

The subjective symptoms may be few in number and inconspicuous, or they may stand out prominently. Soreness and distention of the abdomen, due to gas formation, may occur, but severe pains are usually lacking. By palpation the tenderness may be found limited to certain intestinal areas, thus indicating to some extent the parts involved. In the severer cases the abdominal symptoms may be constant, while in the others they may be called forth only by some slight error in diet, or appear as an accompaniment of a cold, or follow overexertion. The general condition is more or less disturbed. Dulness and headache frequently result from the absorption of poisonous products from the intestinal tract. The appetite is poor, nutrition suffers more and more, and the disturbances in this may assume a very grave character when a large extent of the intestinal mucous membrane becomes involved.

The *diagnosis* of a chronic catarrh of some portion of the intestinal canal usually follows readily from the symptoms. The determination of the involvement of the small intestine is made from the stools chiefly, and involves the same factors as those already given for the acute variety.

The *course* of the disease is protracted. After months or years a functional cure may be achieved, but frequently the enteritis remains until the end of life. It is most dangerous in early childhood and in old age. By it the patient may be so debilitated that intercurrent diseases often prove rapidly fatal.

Treatment.—In chronic catarrhal enteritis the regulation of the patient's mode of life for a considerable period is of greater value than medicinal treatment. This includes avoidance of overwork of any kind, but with sufficient exercise in the open air, a simple diet composed of easily digested food taken at regular intervals, and carefulness about exposure to cold, with the wearing of sufficient warm clothing especially about the abdomen. As those cases in which chronic diarrhea is a prominent feature are more serious than those with constipation, it may here be necessary to keep the patient in bed for some weeks in order to secure as complete rest for the system as possible, to avoid unfavorable external influences, and at the same time to regulate the diet carefully. Small amounts of food should be given frequently and regularly, but sufficient nourishment must be taken if possible to prevent loss in weight. Large quantities at a time are to be avoided. In the severer cases with diarrhea the diet may need to be temporarily restricted to the forms of liquid food recommended above as suitable for cases of acute enteritis. But in general easily digested meats, as beefsteak, lamb chops, chicken, etc., as well as soft-boiled eggs, oysters, toasted bread with butter, baked potatoes, and similar articles may be allowed, together with soups and gruels. Most kinds of fruits and vegetables, and all foods in general that leave much undigested residue or are difficult of digestion, must be avoided, as also very cold drinks, or those containing sugar or acid in any considerable amount, or those highly charged with carbonic-acid gas. Pure water, weak tea, cocoa, milk, kumyss, etc., are to be used, but only in moderate quantities. They may be given warm or moderately cool, never ice cold.

A more liberal diet may be allowed when constipation is marked, and when the food is properly chosen the condition may often be relieved by this means alone. Soups are to be avoided as they appear to arrest peristalsis. Aside from this the articles of food above mentioned may be employed. The additions to these should be such as tend to increase the intestinal peristalsis; the physiological astringents should be avoided. Thus foods containing sugar, honey, grapes, and cooked fruits are often of value, as are also starchy foods. Fats in the form of butter or cream, chicken fat, etc., may be recommended. Generous amounts of buttermilk and kumyss may be advantageously given. But a diet which will leave a large amount of indigestible residue, such as cabbage, beets, fruits containing many seeds, etc., is to be avoided here also as liable to produce too much irritation of the intestinal mucosa. A glass of cool water taken an hour before breakfast often acts favorably.

Nothnagel has emphasized particularly the use of various mineral waters in chronic enteritis as being of much value, not merely by temporarily relieving the symptoms, but at the same time by acting beneficially upon the diseased intestine to favor the repair of the lesions. Naturally the results are more favorable when, as is exceptionally the case, the treatment can be carried out at the sanatoria connected with the various springs; such favorable results being due to some extent to the rest and regular habits there insisted on. In lieu of this the bottled waters or artificially prepared salts are to be employed. Of particular value in those cases in which diarrhea is marked are the waters of Karlsbad and Vichy, those of Kissingen being somewhat less active. When constipation is present certain of the Saratoga waters act very favorably, as do also those from Marienbad in Austria.

Medicinally, chronic enteritis with diarrhea may frequently be benefited by the use of chalk, or chalk and bismuth. Boas recommends the mixture, in equal parts, of the carbonate and phosphate of lime, or the addition to this chalk mixture of one-fifth its weight of bismuth beta-naphthol, a teaspoonful of either preparation being given three times daily. Cathartics should not be employed to relieve the constipation. If the regulation of the diet or the use of spring waters does not accomplish this, other laxatives may be employed; but enemata, either of plain water, or of soap and water, or containing oil in some form, are to be preferred.

The employment of certain strains of lactic acid bacilli in enormous numbers in intestinal conditions accompanied by excessive putrefaction has been advocated. The attempt here is to replace the putrefactive bacteria in the intestine by harmless bacteria. This method of treatment is still in the experimental stage although it has been demonstrated that the intestinal flora can be materially changed by the diet.

When the catarrh is secondary to other chronic forms of disease, as is frequently the case, treatment is to be directed primarily toward the original disease, as frequently it is only by relieving this that the catarrhal condition can be improved.

Croupous or Diphtheritic Enteritis.—This comparatively rare form of enteritis is characterized by the presence of a fibrinous exudate in the tissue and on the surface of the intestinal mucosa, where it forms a false membrane (croupous), frequently combined with more or less coagulation-necrosis of the inflamed tissue (diphtheritic). Anatomically it closely resembles certain forms of dysentery, but the small as well as the large intestine, though to a less extent, may be involved in the inflammatory process, and it has no specific etiological factor.

Various bacteria probably play an important part in the production of this form of inflammation, but the action of these is as a rule secondary to that of other injurious agents. Thus, different mineral poisons, as corrosive sublimate, arsenic, etc., may be the primary cause, and the toxic substances sup-

posed to be formed in certain chronic conditions, as Bright's disease, the cachexia of malignant tumors, etc., and excreted through the intestinal tract, are apparently factors in its production. It occurs occasionally in infectious diseases, as pneumonia, scarlet fever, septic processes, etc. It may develop from a catarrhal inflammation of the mucous membrane, but is not constantly preceded by this. Macroscopically the fibrinous exudate appears as a gray or a grayish-yellow layer of greater or lesser extent on the surface of the mucosa. It may be limited to the tips of the villi or to the crests of the valvulæ conniventes, or the patches may be of considerable size. There may be merely a very thin film of this on the surface of the mucosa or the infiltration and necrosis may extend deeply into the membrane. The solitary follicles may not be involved, or they may be enlarged and take part in the diphtheritic process. In the latter case follicular ulcers are common.

Diphtheritic enteritis, when occurring in the course of severe infections, may not give rise to any symptoms not referable to the primary disease. The condition is at times met with post mortem when not suspected during life. Diarrhea and abdominal pain may exist but are not distinctive. The character of the stools shows nothing to differentiate this from dysentery. The treatment must be symptomatic, with proper attention to the accompanying disease.

Phlegmonous enteritis is to be mentioned as a very rare form of intestinal inflammation. Here there is a more or less diffuse suppurative infiltration, particularly of the submucous coat. It is caused by bacterial invasion and is nearly always secondary to other forms of intestinal disease, such as the various kinds of ulcers, intussusception, strangulated hernia, etc. The symptoms belong rather to the primary disease than to the phlegmonous inflammation. There is no clinical picture by which it can be recognized before death. Charles J. Bartlett.

Enteroclysis.—Enteroclysis, lavage of the intestines, is the title of the subject that we shall discuss, though, to speak correctly, it is but a subdivision of the larger topic, which we shall designate "Intestinal Hydrotherapy." We would define intestinal hydrotherapy as the employment of water in the intestinal tract for therapeutic purposes, the fluid being administered through the anal orifice. This would include:

1. The enema.
2. Irrigation with a single tube —true enteroclysis.
3. Irrigation with a double-current tube, or with two tubes—also true enteroclysis.
4. Recurrent enteroclysis combined with electricity.
5. Proctoclysis—administration by the drop method.

Experiments with Enteroclysis.—We will give a résumé of the experiments which were conducted in the physiological laboratory of the College of Physicians and Surgeons (Columbia University), and which had for their object to determine the relations of this procedure to pulse tension, renal activity, and intestinal absorption; and to ascertain the effects produced by water of different temperatures. The animals employed for these experiments were dogs, and generally those of larger size.

They who are interested in the technical details of the procedures will find them recorded in the *New York Medical Journal*, January 29, 1898, and also in the author's manual,[1] entitled "Enteroclysis, Hypodermoclysis, and Infusion."

I. *The Effect on Pulse Tension Produced by Enteroclysis with Water at Different Temperatures.*—Normal saline solution (a dram of salt to a pint of water) was employed in all cases. With a temperature not lower than 100° F., nor higher than 105° F., the tension of the pulse was slightly increased; with a temperature higher than 105° F., the increase in tension was more noticeable, becoming progressively greater as the temperature of the solution was increased. At 110° F. there were marked increase in the tension of the pulse, increased rapidity of respiration, and changes in the respiratory curve. And from 110° to 120° F., there were progressively increasing tension of the pulse and strong heart action.

With a temperature from 90° F. down to a point as low as 36° or 37° F. (iced water), the tension of the pulse continued to increase as the temperature of the water decreased. After irrigation for about twenty minutes with water at the lower temperatures the heart action became weaker and the pressure fell.

Practical Deductions.—(1) Irrigate at a temperature of 100° to 102° F., or even as high as 104° F., if increase in pulse tension is to be avoided.

Though physiologically a slight increase in the tension of the pulse occurs at these lower temperatures, clinically none can be detected.*

(2) If a moderate increase of pulse tension is not objectionable, a temperature of 105° to 108° F. can be employed.

(3) To increase rapidly the pulse tension and stimulate the heart, employ the fluid at a temperature of 110° F., and increase the heat gradually to 120° F. This is excellent in shock; before, or during severe operations, to prevent shock; and, from the commencement of chloroform anesthesia, to prevent the sudden dilatation of the vessels.

(4) Cold is a temporary stimulant; later, it acts as a depressant. It should therefore be employed with caution. More patients have an idiosyncrasy as regards cold than as regards heat.

II. *Effect of Enteroclysis on Shock from Hemorrhage.*—The degree of the tension of the pulse was first noted in an animal, and then, after blood had been withdrawn from the femoral, the effects on the pulse tension and the heart were observed. The report of a single experiment will suffice:

Weight of dog, twenty pounds; blood pressure, 155 millimeters; 50 c.c. of blood removed at a time, until 509 c.c. in all had been withdrawn. Under the influence of these successive removals, the pressure fell rapidly to 112 millimeters. Enteroclysis was at once begun with normal saline solution at 110° F., and the heat was rapidly increased to 120° F. Immediate rise of blood pressure followed, and in ten minutes it reached 140 millimeters, and remained steady at this point; the heart was by this time acting with fair force (see Fig. 2057).

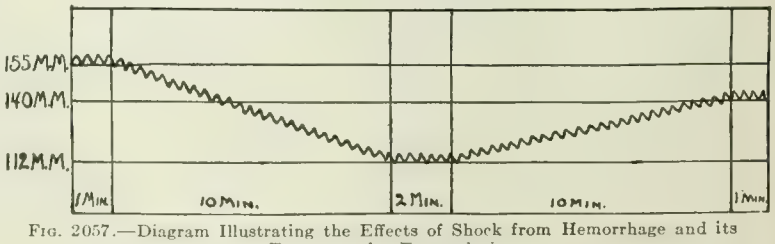

Fig. 2057.—Diagram Illustrating the Effects of Shock from Hemorrhage and its Treatment by Enteroclysis.

Deduction.—In shock from hemorrhage irrigate with normal saline solution at a temperature of 110° to 120° F., preferably at 120° F.

III. *Effect of Enteroclysis upon Body Temperature.*—Dogs were employed for the experiments, which were conducted in a room of a temperature of about 72° F.

* This statement is in regard to the pure reflex effect of the temperature upon pulse tension —not in relation to effects produced by absorption of the fluid.

Irrigation was continued for about twenty minutes, the temperature of the water being gradually raised from 110° to 120° F. The results were: a gradual rise of the body temperature; in the axilla the increase amounted to 1° F.; the temperature of the aortic blood increased 0.5° to 0.8° F.; the tension of the pulse increased markedly.

Hot irrigation was then suddenly changed to cold, the water having a temperature of 36° to 37° F., and this was continued for twenty minutes, with the following results: Axillary temperature fell 2° F.; blood temperature fell 1° F.; pulse tension at first continued high, but later it fell, and the heart action became rapid and feeble. With a temperature of from 100° to 105° F., the irrigating fluid exerted no appreciable influence upon the body temperature. Water temperatures of 150° to 110° F. caused slight increase of body temperature in the course of twenty minutes; while at from 90° to 60° F. they caused slight fall in the body temperature in the same period of time.

With enteroclysis at a temperature of less than 60° F., there was a loss of body temperature in the course of twenty minutes; but it was not very marked until the extreme degrees of cold were reached. There were idiosyncrasies in the animals. Cold at first stimulated, but, when prolonged, it depressed the circulation.

Deductions.—1. Hot irrigation at 110° to 120° F., when prolonged, increases the temperature of the body and blood, and hence its value as a means of stimulating the heart. In shock and in allied conditions its great value, especially when water at a high temperature is employed, has been demonstrated clinically.

2. In severe fevers it might not be advisable to employ enteroclysis at a high temperature, and yet it is possible that the etiological conditions may radically modify this rule.

3. Cold irrigation reduces temperature and at first stimulates the circulation; but later it is a depressant. It has been employed to reduce temperature in dysentery, etc. I believe that it should be cautiously used and at a temperature not below 70° to 80° F. at first, and only in sthenic cases. It should be employed for a brief period, and friction during its application might be advisable.

Cold rectal irrigation is safer, and iced water has been so employed for rectal congestion for a period of over thirty minutes continuously and with a successful issue.

IV. *Effect of Enteroclysis, with Water at Different Temperatures, on Renal Activity and Intestinal Absorption.*—The experiment was made in the following manner: The manometer was in each case attached to the carotid artery, to enable the observer to note the effect on pulse tension; one ureter was catheterized and the catheter was so adjusted that the drops of urine impinged on a lever supported by a tambour, each movement of which was transmitted to a second tambour, which supported a registering pen; every drop of urine was thus registered on a revolving kymograph, in the form of an inverted V. The urine was collected and measured. The opposite ureter was also catheterized and the urine measured.

Enteroclysis with normal saline solution at temperatures of from 110° to 120° F. increases renal secretion in the course of ten minutes, and very markedly so in twenty minutes. There is a marked increase of pulse tension. Note the *two cycles* of the increase of the secretion. Thus, for example, at the end of ten minutes the increase in secretion corresponds to the maximum height of the blood pressure obtained by enteroclysis at 120° F., and to the commencement of temperature increase (see experiments just described). With enteroclysis at temperatures of from 105° to 110° F., there is, at the higher temperatures, a slight increase of secretion in ten minutes and a considerable increase in twenty minutes; but at the lower temperatures there is no increase until after the lapse of twenty minutes.

With enteroclysis at temperatures of from 100° to 103° F., no increase in renal secretion is noted until the operation has been kept up for twenty minutes, and then the increase is considerable. There is a slight increase in pulse tension. Noteworthy is the single cycle of increased secretion.

That the increase in renal activity which occurred in the course of twenty minutes, from an enteroclysis with normal saline solution at temperatures varying from 100° to 120° F., was due to absorption of the fluid from the intestine, was demonstrated as follows: A weak solution of potassium ferrocyanide, 1 to 40,000, was added to the normal saline solution in each case, and the urine, as it fell into the receiving vessel, was tested every fifteen to thirty seconds with chloride of iron. On every occasion the Prussian-blue reaction was secured at the end of twenty minutes, and this occurred synchronously with the increase of renal secretion. This experiment further demonstrates the fact that intestinal absorption occurs from the large intestine (colon or rectum) in about twenty minutes.

The following interesting fact was noted: A small enema, or an enteroclysis, of normal saline solution, which had a temperature of 99° to 100° F., and which contained a weak solution of potassium ferrocyanide, produced, at the end of about twenty minutes, increased diuresis, as demonstrated by the greater number of drops of urine registered on the kymograph at this time, synchronously with the appearance of the Prussian-blue reaction in the urine in response to the chloride-of-iron test; yet no discoverable rise of pressure occurred in the manometric tracings. The increased secretion was therefore evidently due to the action of the saline solution on the kidney cells. This corresponds to the results obtained by Foster in his experiments with infusion; for this authority noted that a normal saline solution, administered in so small an amount that no rise in pulse tension could be detected with the manometer, caused a profuse diuresis.

The effects of cold irrigation on renal secretion were found to be as follows: Enteroclysis with normal saline solution at all temperatures from 100° F. to iced water (36° to 37° F.) produces diuresis in about twenty minutes, this effect being due to absorption of the fluid from the intestines. The pulse tension is increased as the temperature is lowered, and hence, by this means, secretion is further increased. With the lower temperature, however, in about twenty minutes the animal frequently goes into shock and renal secretion then ceases. Cold enteroclysis, or enemata, would seem, therefore, to be contraindicated in renal disease.

We believe that general deductions from physiological experiments on healthy animals cannot be universally applied to the human subject, and this is doubtless the true explanation why the pure physiologist quite frequently leads us to erroneous conclusions. In the practice of medicine, the results secured are often markedly modified by the existing clinical conditions. For example, enteroclysis at a temperature of from 110° to 120° F. was recommended when the pulse tension and temperature were not high. Nevertheless, I have secured excellent results in acute uremic poisoning, with high pulse tension and a temperature of 102° F., from an enteroclysis with normal saline solution at a temperature of from 115° to 120° F., kept up for a period varying from half an hour to one hour. Profuse sweating, diuresis, and bowel action followed, and there was also a marked fall in pulse tension. Other observers have had the same experience.

If the blood-vessels are atheromatous, a great degree of heat might be undesirable. Nitroglycerin, gr. $\frac{1}{100}$, given previously to the enteroclysis, might be of value.

Effects of Irrigations, or Enemata.—They may be summarized as follows:

1. The local treatment of diseased conditions, as of catarrhal colitis.
2. The relief of congestion or acute inflammation, as of the rectum or prostate.
3. The absorption of inflammatory products as in pelvic peritonitis or postuterine adhesions.
4. To replace the loss of fluid from the body as in cholera or the relief of thirst.
5. To dilute the poison of disease, as in uremia.
6. To increase the flow of blood to a part, as in insufficient menstruation—by the use of warm irrigations.
7. To check hemorrhage (extreme cold or heat). Locally as in bleeding ulcers of the rectum or from hemorrhoids; in an adjacent organ as in uterine hemorrhage.
8. Reflex effects through the sympathetic ganglia, on the circulatory apparatus, on the secretions, as a tonic stimulant, revulsive effects, and reflex effect on a distant organ. On the circulatory apparatus as in shock; on the secretions as in the production of sweating, bowel action, and urinary secretion in uremia. As a tonic stimulant as by the use of the alternate hot and cold douche in diminution of erectile power or in atonic constipation. The revulsive effect, as by the production of bowel action in apoplexy. The reflex effect on a distant organ as from enemata in jaundice.
9. The relief of pain and irritability as in spasm of the sphincter or vesical irritability in the male.
10. The effect on the heat centers—the temperature can be raised in shock by hot irrigation, or lowered in fever by cold irrigation or enemata.
11. Simple cleanliness by removing undigested food products and preventing autointoxication.
12. Antispasmodic, by relieving spasm of colic.
13. Mechanical, as in intussusception by exertion of pressure.
14. Water as a vehicle—the nutritive or medicated enema.

From these effects one can readily deduce the clinical applications.

Clinical Applications.—Hot saline enteroclysis is an excellent remedy in acute uremic poisoning, in oliguria, in renal congestion, or in any dropsical condition due to oliguria, such as pulmonary edema, pleurisy with effusion, ascites, etc. It aids elimination of the toxins, through the kidneys, in typhoid fever, sepsis, septic endocarditis, diphtheria, etc. Many practitioners have obtained excellent results by the employment of this mode of treatment.

A temperature of from 110° to 120° F. gives the best results, due to the double cycle of increase in the urine, attributable to the several causes heretofore noted in the account of the experiments.

Renal disease with polyuria seems to contraindicate the employment of this method; or, at all events the existence of the latter symptom necessitates a cautious employment of the method. In a case of enlarged prostate, I found that prolonged irrigation aggravated the polyuria.

Among other indications are dysentery, intestinal catarrh, intestinal hemorrhage (particularly in the large intestine where hot or cold astringent injections are of service), intestinal toxemia, intestinal dyspepsia, diarrhea, thirst, constipation, fecal impaction, jaundice, intestinal paresis, tympanites, renal colic, intestinal colic, shock, and in inflammatory conditions of the genitourinary organs of both sexes.

The Enema.—There are two forms of enemata—the high and the low. The *high enema* is administered through a colon tube, or long catheter, to which is attached a fountain syringe, or a vessel arranged on a similar principle. The bag should hang at a height of two or three feet above the patient, and the tube should be pinched sufficiently to allow the fluid to enter slowly, so as not to excite intestinal spasm. The colon tube, well lubricated with olive oil or vaseline, is inserted into the rectum and pushed gently into the bowel for a distance of from twelve to fourteen inches. Its progress is facilitated by allowing the solution to flow, as the tube is pushed farther up into the bowel. In infants a small catheter (No. 16 or No. 18 French) can be used. The water employed for the enema should preferably be sterile (boiling it for about fifteen minutes is generally sufficient). If a Davidson syringe is used, the flow is often intermittent and forcible, exciting spasm of the bowel, and hence it is better to use the fountain syringe.

Position of the Patient.—The dorsal position, with the hips or the foot of the bed elevated, is best. The knee-elbow posture is at times employed for a high injection.

Quantity of the Solution; Temperature; Indications.—When it is desired, in a case of fecal accumulation, tympanites, etc., to secure an action of the bowels, the following mixtures may be employed (in the case of an adult): one quart or a quart and a half of simple water at a temperature of from 101° to 104° F.; or sufficient soap (brown or castile) may be added to this to form suds; or, finally, if there is tympanites, ℥ ss.–j. of spirit of turpentine may be added to the last. Olive oil or glycerin—℥ ss.–j.—constitutes a valuable adjunct. For the purpose of softening fecal accumulations I have employed as much as Oss.–j. of oil or of glycerin at a single injection. In the case of an infant, from half a pint to a pint and a half of water—with an addition of ℥ i.–ij. of olive oil, if required—is the average quantity employed at an injection.

The enema is also of value in apoplexy and in infantile convulsions. It is important to remember that dilatation of the intestine and loss of muscular tone may result from the too frequent employment of the enema or the use particularly of too large injections. A small enema of a pint or a quart, particularly if given *in the knee-chest* position, is extremely valuable. It will do the work of a large injection in the dorsal posture.

Kussmaul's method of oil irrigation for the treatment of chronic constipation appears to be a valuable therapeutic measure. He employs about a pint of olive oil by enema, at bedtime, injecting it slowly through a long tube; the patient lying down during the operation, first on the left side, then changing gradually to the dorsal position, and finally resting upon the right side. Gentle massage is kept up while the oil is being injected. If possible, the enema is to be retained over night.

For stimulation in shock—to whatever cause it may be due—in heart failure during anesthesia, in uremia, oliguria, suppression of urine, septic conditions, cholera, diphtheria, etc.; and as a means of replacing to some extent the loss of fluid from the body, such as occurs in gastroenteritis and after certain surgical operations, the enema may be of great value. The fluid should be injected slowly through a long tube, with the hips of the patient, or the foot of the bed, well elevated. The retention of the injected fluid must be carefully provided for. Physiological saline solution (one dram of salt to the pint of water), at a temperature of from 110° to 120° F., should be employed for any of these conditions. In an adult the quantity to be injected at any one time should not be less than one pint nor more than two quarts, and the injection should be repeated every one to three hours, according to the indications that may be present. Some patients, however, will not retain even as much as a pint of solution and in such event even small quantities, ℥ iv.–viii. are of value. In children a proportionately smaller quantity of fluid should be used. In addition to the normal saline solution other solutions may be used to advantage. These are enumerated in the section on Double-Current Enteroclysis.

The method here described is of value in dysentery, typhoid, cholera, gastroenteritis, etc. It should be more correctly classified under enteroclysis with a single tube, but it is a difficult matter to draw a sharp line of division between the two kinds of enteroclysis.

In cases of jaundice or of hemorrhage (intestinal or in adjacent organs), and in those in which it is desired simply to reduce temperature, the same method is to be employed, but the solution should have a temperature of from 90° to 70° F., or even less. Cold should be employed in sthenic cases only, and even then with caution. In cases of hemorrhage or of jaundice a temperature of from 110° to 120° F. at times gives the best results. Normal saline solution is commonly employed under these circumstances. Some advocate the injection of fresh beef blood to check intestinal hemorrhage.

For relaxing spasm, such as occurs in renal, biliary or intestinal colic, as much as one or two quarts, at a temperature of from 101° to 104° F., is to be injected, in the case of adults. In the case of children a smaller quantity is to be employed. At times, especially in intestinal colic, a temperature of from 110° to 120° F. gives the best results.

(The nutritive enemata are described in Vol. I., under the head of *Alimentation, Rectal.*)

Intussusception.—In this condition the enema may often prove a useful therapeutic agent through its mechanical effects. When it is administered for this purpose, the patient's hips should be elevated and the shoulders depressed. Some advocate Trendelenburg's position. Emmett Holt, in the case of infants or young children, places them in the dorsal position, with the thighs flexed, and from time to time during the injection he inverts the patient, gently manipulating the tumor through the abdominal wall. "Hydrostatic pressure should supply the force required. In the case of adults the long colon tube should be employed, while for infants a small catheter, No. 18, will be found better suited to the work. As regards the height at which the fountain syringe should be hung, I may state it to be four or five feet above the patient; this elevation giving a pressure of not over three pounds to the inch. Occasionally it may be necessary to place the bag at an elevation of six or even eight feet, in order to increase the pressure, but this is rarely advisable." (Holt.)

Experiments made upon the cadaver, for the purpose of throwing light upon this question of pressure, furnish results which are apt to be misleading; and it must be remembered that great pressure upon the wall of a viscus like the intestine, especially if it be in a damaged condition, is likely to prove dangerous.

The solution to be employed should consist either of water or of normal salt solution. Holt also advises milk and water or thin gruel as being less irritating than plain water. He advocates at times the injection of air. The injection of oxygen, as employed by Dr. Clement Cleveland, in postoperative intestinal obstruction, or paresis, should be of value.[2]

"The temperature of the fluid employed should be at some point between 100° and 105° F., and in all cases an anesthetic should be administered. The quantity of fluid to be injected should vary according to the position of the intussusception. The best guide as to the amount is furnished by *the degree of tension of the abdominal walls.* During the progress of the injection the buttocks should be held tightly together, to prevent escape of the fluid. If at any moment the tension should seem to be too great, the pressure upon the buttocks may be withheld and some of the fluid allowed to escape. As a further guide, in estimating the amount of fluid to be injected, we can remember that the colon of an infant, six months old, will hold about a pint without distention, and that, at the age of two years, it will hold two, or possibly three, pints. The adult colon holds considerably more than a gallon (Weir says nine pints, or a little over) without distention. Pressure should be kept up for from ten to twenty minutes, or even for half an hour. If the injection fails to reduce the intussusception within this time, then stop. A second attempt can be made within two hours, and if failure again results, then resort to laparotomy." This is the advice given by Holt. My own personal view is, that it is better to resort to operative interference after one failure of the injection.

The *low enema* is one in which the fluid injected does not extend beyond the rectum. For this purpose a fountain syringe, provided with the short rectal tip, well lubricated, is to be preferred. A Davidson syringe or even a suitable pattern of a hard-rubber hand syringe may be employed when only a small quantity of fluid is to be injected.

In this form of enema the patient may occupy either the dorsal or the semi-oblique or the sitting posture; and, when solutions of a high temperature are employed, it is well to lubricate the nates and the anus as far as to a point beyond the sphincter. If the enema is to be retained, the patient should assume either the dorsal posture, with the hips elevated or what is known as the Sims position.

The conditions which call for the use of the low enema do not differ materially from those which suggest the desirability of employing the high variety. In fact, the difference often amounts simply to this: in one set of cases it seems desirable to inject a small mass of fluid, while in the other a larger quantity appears to be required. Thus, in shock, uremia, etc., from two to six ounces of normal saline solution, at a temperature of 110°–120° F., is injected; the intention being that it should be absorbed.* Such an injection should be given very slowly, and, as the tip is withdrawn, a towel should be slipped over the anus, and the buttocks should be held together for some minutes therafter to prevent escape of the fluid. Then, again, small enemata of starch water containing ℥v.–xij. of laudanum, or of tincture of belladonna, etc., often prove useful in allaying irritability of the rectum or adjacent organs. Finally, in cases of dysentery, etc., after thorough irrigation of the bowel, enemata of this class are generally of value.

When it is desired that the fluid injected should be retained for a short time and then evacuated, the quantity employed should vary from two ounces to a pint, according to the circumstances of the case. The temperature of the fluid should vary in a similar manner; hot solutions (from 110° to 120° F.) being best suited to certain conditions, and cold (from 90° to 60° F.) to others. There are even cases—those of internal hemorrhoids, for example—in which iced water may be used to advantage. On the other hand, there are individuals who show a decided repugnance to cold enemata.

Enteroclysis with a Single Tube.—Enteroclysis with a single tube may belong to either of the two varieties—the high or the low. There are several methods. Thus, for example, a colon tube or large catheter is introduced into the bowel and a fountain syringe or a funnel is attached. A definite quantity of fluid is allowed to flow in, and then the fountain syringe is detached, or the funnel is lowered below the level of the patient and the solution evacuated. This procedure is repeated a second time, or several times, according to the indications, or until the fluid that returns is quite clear. As already stated above, both the temperature and the amount of the fluid employed should vary according to the individual circumstances of each case.

A Y-shaped or T-shaped glass tube may be attached by its stem to the rectal tube, and by its forks to the fountain syringe on the one hand, and to a carry-off

*In these conditions an even larger quantity, if it can be absorbed, is preferable.

tube on the other. By checking the outflow through the latter while allowing the inflow to continue, and then by arresting the latter and allowing the fluid to escape through the carry-off tube, one can irrigate the intestine in a satisfactory manner.

Still another method is to allow the injected fluid to be ejected by the patient alongside the tube, immediately after which a fresh supply of the fluid is again injected. This operation can be repeated as often as may be desired. It will be found useful not only for cleansing purposes but also for the relief of such conditions as shock, uremia, hemorrhage, etc. The mode of procedure, in the case of an infant, is thus described by Dr. L. Emmett Holt, who places the ileocecal valve as the limit which the fluid may reach: "The child is placed on the back, thighs flexed, buttocks brought to the edge of the table, clothing protected. The fountain syringe at a height of four to five feet; a flexible rectal tube, or soft catheter, No. 18–20 American scale, is employed; an extra eye may be cut near the tip. The catheter is oiled and just after the tip is inserted into the anus the water is turned on. This renders it stiffer, and it passes more readily. It is pushed in twelve to fourteen inches. Usually a pint and often a quart will be introduced before any water returns. The water is evacuated from time to time alongside the catheter and often with considerable force; hence a towel should be spread to fall like a screen over the anus to protect the operator. The washing should be continued until the water returns quite clean. Gentle kneading of the abdomen should be employed during the early part of the irrigation to facilitate the passage of water into the

Fig. 2058.—Enteroclysis with Single Tube. Case of an infant.

upper part of the colon. The temperature, in most cases, should average 101° F. At the end of the irrigation, the tube of the fountain syringe is detached and the fluid which remains allowed to escape through the catheter before removal of the latter. The colon of a six-months' infant holds a pint without distention, and, at the age of two years, two to three pints."

A convenient modification of the operation is shown in the accompanying illustration (Fig. 2058).

Enteroclysis with a Double Continuous Current.—The principle of double-current irrigation is quite old; the instrument of Bodenhamer was probably the first double-current rectal irrigator devised. Many other irrigators have been employed, such as two tubes or catheters, or a large double-current catheter, etc. When it is necessary to improvise a double-current irrigator, this may be accomplished in the following manner: Take two catheters—the smaller one for the entering current, the larger for the outflow—and pass them through a perineal pad of gauze and cotton, covered with oiled silk, or through a dress-shield, or a piece of oil cloth, marble cloth, or rubber sheeting.

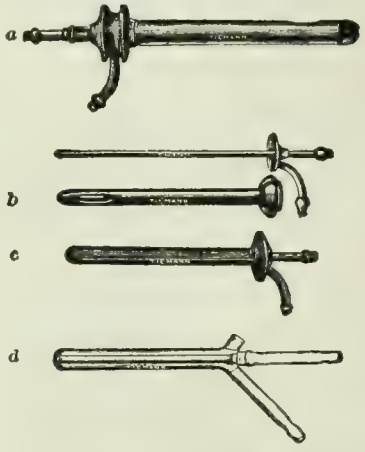

Fig. 2059.—Author's Irrigating Tubes. *a*, Flexible irrigator; *b* and *c*, more recent models; *d*, glass irrigator, with side opening (closed by a cork) for cleansing purposes.

One can furthermore attach a Y or T tube by means of a short piece of rubber tubing to the central tube of the recurrent irrigator. One branch of the Y may be attached to a fountain syringe containing hot normal salt solution and the other branch to a fountain syringe containing cold solution. An alternate hot and cold intestinal douche can thus be given. This method would be of value as a stimulant in atonic constipation and in diminution of erectile power—the irrigation in the latter case being administered low in the rectum.

In the accompanying figures are shown several of the author's latest patterns of irrigating tubes (see Fig. 2059, *a*, *b*, *c*, *d*).

Precautions to be Observed before Inserting the Tube.—Allow the irrigating fluid to flow from the tube until all the air has been expelled; then check the flow. As the tip of the instrument passes through the sphincter, start the flow in order to force the mucous membrane away from the irrigator and from its fenestræ. Attach the fountain syringe to the central tube and the carry-off tube to the larger curved lateral tube. By alternately pinching this and the tube of the fountain syringe, the quantity of fluid entering and escaping can be regulated. As the outflow is larger than the inflow, unless the outflow is checked no fluid will pass up the bowel.

Insertion of the Instrument.—The tube should be well lubricated and inserted with a gentle rotary motion, and not forced in. The tip of the instrument should be directed slightly backward toward the sacrum, and the fluid allowed to flow at the moment when the tip passes the sphincter. If the flow ceases, rotate the tube slightly or withdraw it slightly while rotating, and push it back. If the outflow seems to be obstructed, stop the inflow and then force fluid back through the outflow tube with a small hand syringe, or detach the fountain syringe and force the flow back through the outflow tube for

an instant. Sometimes "milking" the outflow tube with the fingers will start the flow. Avoid pressing the tip of the instrument against the wall of the bowel, or directing the current against it, as either of these procedures is irritating.

Distance to which the Irrigator should be Pushed up into the Bowel.—The rectal tube should be inserted for a distance of from one-third to one-half its length in prostatic cases, etc., and in its entire length when high irrigation is to be carried out. In actual practice it is found that the introduction of the short tube to its full length, provided the patient's hips are elevated, gives as good results in high irrigation as does the colon tube.

Withdrawal of the Instrument.—Do not withdraw the instrument like an ordinary tip, lest the mucous membrane catch in the fenestræ, but rotate it slightly, first in one direction and then in the other, as it is being withdrawn. By observing this precaution the physician will not be likely to experience the accident just described.

Cleansing the Irrigators.—To clean the stiff tubes, unscrew the central tube and withdraw it. To clean the flexible tube, unscrew the accessory cap and

Fig. 2060.—Enteroclysis in the Semi-recumbent Position.

loosen the main cap, meanwhile holding the rubber fitting of the central tube firmly, to prevent twisting the central linen catheter; push the caps along the central tube to nearly the end, then withdraw the hard-rubber tip from the main outer tube and with it about half an inch of the central linen tube; next unscrew the tip, holding the catheter firmly just below it; and finally withdraw the central tube, as in the hard-rubber instrument. If the attempt were made to unscrew the flexible tube, it would readily tear. The flexible tubes should not be allowed to remain in any solution except for a moment, as the central tube readily softens and collapses. Should this occur, a wire passed through it generally remedies the difficulty. The central tube is often made of a linen catheter. The flexible English catheter (such as has the stylet) is much more durable; the ends do not fray so readily, nor does it crack so easily, and it is cheap. No. 7 is a good size; it can be cut in lengths to suit, and the hard-rubber fittings will cut their own thread on it. A fresh central tube can thus be used in every case, and the outer tube and fittings can be disinfected.

Enteroclysis in the Semi-oblique (Half-sitting) Posture.—Dr. William H. Thomson's method. This has been employed in pulmonary edema and in pleurisy with effusion, when, because of respiratory difficulty, the patient was unable to lie down (see Fig. 2060).

The Different Positions of the Body in which High

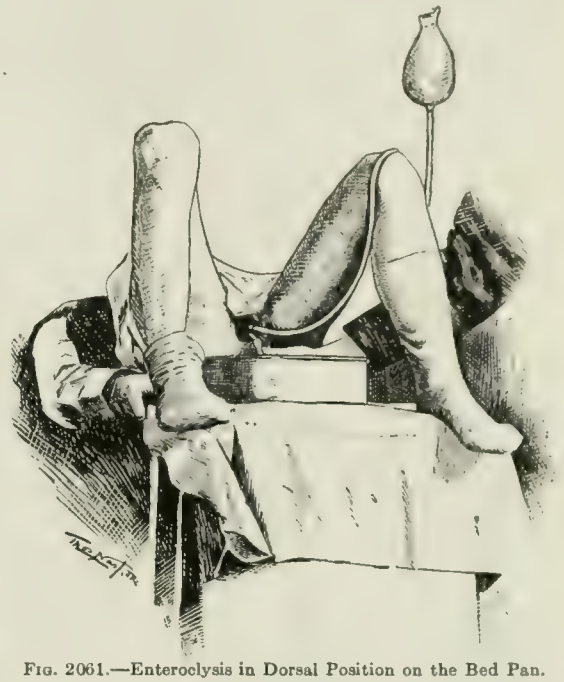

Fig. 2061.—Enteroclysis in Dorsal Position on the Bed Pan.

Irrigation may be Practised.—The first position is that in which the patient lies upon his back, with his hips elevated and his shoulders at a lower level. A bed pan, preferably a douche pan, is placed be-

Fig. 2062.—Enteroclysis in Dorsal Position without Bed Pan.

neath his buttocks (see Fig. 2061). This receptacle, however, may be dispensed with, as a rubber sheet, if properly adjusted, will answer sufficiently well (see Fig. 2062). The patient may also lie on either

side, with the hips elevated and the shoulders at a ower level (see Fig. 2063). Instead of a rubber sheet, a Kelly's pad may be employed. The method used in the case of an infant is depicted in Fig. 2064.

What is known as the *method by rotation*[3] may be described as follows: The patient is placed on the left side, with the hips elevated, and about a pint and a half of the solution is allowed to flow into the descending colon; the outflow tube is then pinched and the patient is gradually rotated first to the dorsal position and then to the right side. As the next step

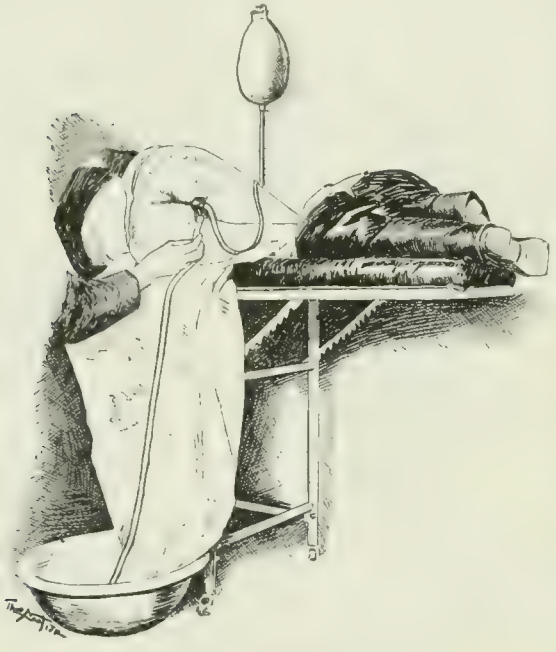

Fig. 2063.—Enteroclysis in the Sims Position.

in the procedure the shoulders are elevated above the level of the hips (the patient still being on the right side), in order that the fluid may gravitate into the caput coli. Then the steps just described are reversed, the outflow tube is released, and the fluid is permitted to escape. This method resembles Kussmaul's technique for irrigations with oil.

Douglas H. Stewart[4] of New York has devised an ingenious and convenient method. For continuous irrigation, he partly fills a wash boiler with normal saline solution at the desired temperature, and this is kept hot by the addition of fresh hot solution; he hangs a gallon fountain syringe about six or seven feet above the patient. He employs a hand pump to force the solution from the wash boiler through a connecting tube to the fountain syringe above. This simplifies the entire procedure and one does not have to disturb the bag in order to refill it. In addition, the outflow tube of the irrigator is left open, as there is sufficient force on account of the height of the bag to carry the fluid well up the large intestine. Distention is carefully watched for and the entering current diminished by lateral pressure on the tube of the fountain syringe, or the entering current is shut off. The patient lies on the bed or couch in the dorsal position, or on the side with the buttocks over the edge of the bed—the outflow tube passing into a pail or slop jar. The writer has had this method employed on himself with excellent results.

The indications for employing double-current enteroclysis may be deduced for the most part from the following paragraphs.

Quantity and Temperature of the Solution.—In colitis, dysentery, typhoid, intestinal dyspepsia, the various forms of diarrhea, constipation, fecal impaction, etc., a quantity equal to from six ounces to one pint and a half may be allowed to flow into the bowel before escape is permitted. Enteroclysis may be employed once or twice daily, and the total amount of fluid used at each sitting should not be less than two quarts. In some cases as much as several gallons has thus been utilized. If there are no special contraindicating circumstances the flow should be kept up until the escaping fluid is quite clear. The temperature of the fluid used should be from 101° to 105° F. On the other hand, in sthenic cases, if there be a high temperature—as in dysentery, gastroenteritis in infants, etc.—irrigation with a solution at from 90° to 75° F. may be employed, to aid in the reduction of temperature. Cold should be used cautiously, and I believe that it is contraindicated if there are renal complications.

For the relief of the spasm which accompanies renal, biliary, or intestinal colic, it is a good plan to allow from six ounces to one pint of a hot fluid (saline solution at a temperature of from 101° to 103° F.) to remain continuously in the bowel for fifteen minutes or longer. At times a solution having a still higher temperature

Fig. 2064.—Enteroclysis with Double Tube. Case of an infant.

(from 110° to 120° F.) acts better. This is often the case in intestinal colic, in which condition the hot solution aids in expelling flatus.

In all conditions in which it is desirable to stimulate the circulation, to increase renal secretion when insufficient, or to eliminate toxins through promotion of diuresis, etc., the quantity of the solution to be kept continuously in the bowel should average from a pint to a quart; and the enteroclysis should be kept up for from half an hour to an hour. If we wish to secure the best results under the conditions referred to, we should employ normal salt solution at a temperature somewhere between 110° F. and 120° F. In addition to the conditions last named and to those enumerated in the earlier part of the article, the following may be

named: sepsis due to any cause, as from peritonitis septic endocarditis, cholera, typhoid, diphtheria, etc.; malarial poisoning (to check or abort a chill); the various dropsical conditions, etc.

Enteroclysis, as may readily be supposed, has proved to be of use in gynecology. Thus, for example, its usefulness in the case of an unmarried woman, as a substitute for vaginal douching, deserves special mention. It may be employed, in the form of hot enemata of normal saline solution (at a temperature of from 110° to 120° F.), for promoting the absorption of pelvic exudations, for the relief of leucorrhea, of ovaritis, of shock, etc., and in many other conditions.

Fig. 2065.—Self-irrigation of the Prostate per Rectum.

In genitourinary and rectal affections—such as inflammation of the prostate or bladder (see Fig. 2065), retention of urine, spasmodic stricture of the urethra, chronic or acute inflammation of the urethra, internal hemorrhoids, etc.—enteroclysis often affords great relief. In cases of intestinal paresis and of intestinal obstruction injections of oxygen have been found useful by Dr. Clement Cleveland of New York.[2]

Solutions that may be Used in Enteroclysis.—*Flaxseed tea*, made thin and oily, is of value in catarrhal conditions of the intestine, especially if accompanied by constipation; it also aids absorption of exudations. Gum arabic or slippery elm solutions have an excellent effect on an irritable mucosa.

Physiology salt solution, a dram of salt to a pint of water; useful for cleansing purposes; bland and especially safe for children; useful as a circulatory stimulant, as a diuretic, and to eliminate toxins.

Oil of peppermint or *of cinnamon* (five to fifteen minims to the pint) may be added to the salt solution for cleansing purposes (William H. Thomson).

Boiled water, with boric acid (from half a dram to a dram to the quart, or even stronger), or with permanganate of potassium (from ten grains to ʒ ss. to two quarts of water); useful when there is marked fermentation or foul odor. A similar solution of bichloride of mercury (1 to 10,000) has been successfully employed (two quarts at each irrigation daily) in membranous (croupous) colitis of a septic type.* Bichloride solution should be used only with a recurrent irrigator. In dysentery it is also of service. Stronger solutions do not appear to be necessary. Solutions of carbolic acid and of camphor have been found to be irritating. Rovacs and others employ quinine solutions (1 to 1,000) in amebic dysentery. J. B. Thomas has carried on extensive researches at Manila and finds the following solutions of great value in this type of dysentery: acetozone 1:1,000 (most destructive to amebæ); alphozone 1:1,000; protargol or argyrol 1:500; quinine bisulphate. 1:750 to 1:500; silver nitrate 1:2,000; thymol 1:2,500; permanganate of potassium 1:2,000. Hydrogen peroxide five per cent. to ten per cent. solution at a temperature of 45° F. or less is also of value. One to two liters of these solutions should be given by high enema and retained for five to fifteen minutes, once to several times daily in irritable cases; when it is difficult for the patient to retain the injection recurrent enteroclysis is preferable. Solutions of tannin (one to two per cent.) are valuable in cholera. Tannic acid, tannin, witch hazel, and other astringents, are useful in dysentery. In chronic conditions injections of silver-nitrate solutions (gr. x.–xx. to the quart or even the pint), to be followed by the saline solution to prevent overaction, are of service. Protargol or argyrol 1:1,000 to 1:500 are also useful. The same solutions are of value in acute and chronic bacillary dysentery. Solutions containing listerine, boracic acid, borolyptol, borax, bicarbonate of sodium, or powdered alum (a dram of the latter to the quart of water, or even a stronger solution), are of service.

The writer has already referred to the value of permanganate of potassium for irrigation when the stools are of foul odor. Douglas H. Stewart recommends the following when there are foul odor, fermentation, putrefaction, and excessive bacteria:

Commercial acetic acid	ʒ ss. (1 tablespoon).
Chlorinated lime	ʒ ii. (2 teaspoons).

Dissolve in one quart of water.

Then add nine quarts of *plain* sterile water (salt is incompatible with acetic acid). A requisite portion of the ten quarts is used for irrigation. The solution eliminates chlorine and yet does not seem to irritate. If salt solution is desirable, omit the acetic acid and substitute two teaspoonfuls of commercial sulphuric acid thus:

Commercial sulphuric acid	ʒ ii. (2 teaspoons).
Chlorinated lime	ʒ i. (1 teaspoon).
Physiological salt solution	10 quarts (liters).

The recurrent method of irrigation should be used for these solutions. Acetozone solution 1:1,000 the writer also finds of value in these putrefactive cases.

Hemorrhage from the Rectum or Colon.—Tannic acid grs. xv.–ʒ i. in a quart of hot water (120° F.), or in iced water, or the same quantity of alum or tannin is of service. Tremolière has demonstrated that a five per cent. gelatin solution containing two per cent. chloride of calcium has a local styptic effect. Gelatin of course is of value. An injection of Tremolière's solution is of service. The writer has employed with success recently a ten per cent. gelatin solution containing grs. xv.–ʒ ss. lactate or chloride of calcium and adrenalin chloride (1:1,000)—ten drops for severe hemorrhage from hemorrhoids—the solution being given cold and administered by enema.

Needle-douche; Nebulizer.—F. B. Türck recommends these instruments. The colon needle-douche may be of some value for local treatment by means of an alternate hot and cold spray for the atonic type of constipation. The nebulizer is recommended by its inventor for spraying oil of cloves or cinnamon into the colon for their antiseptic, analgesic, and vasomotor effect.

Recurrent Enteroclysis Combined with Electricity.—Intrarectal electricity was formerly administered by means of a saline injection followed by

* Mercury cyanide, 1–10,000, after Cumston's formula (mercury cyanide, 0.5 gram, sodium borate (C.P.), 1 gram) is preferable. It is less irritating, does not coagulate albumin, and in the alkaline solution is more stable and hence less toxic.

the insertion of Bondet's electrode or an instrument of similar type. It is difficult for the patient to retain the enema and repeated evacuations necessitate the withdrawal of the instrument. The writer devised a method some years ago which is simple and practical. His instrument consists of a recurrent irrigator, external tube of hard rubber, with a metal internal tube, with an attachment to the latter for a battery pole. To the other pole of the battery a sponge is attached and the latter is placed over the abdomen. Continuous enteroclysis is given with hot normal saline solution, the water carrying the electric current (or rather making the connection). Fig. 2066 illustrates this device.

Fig. 2066.—Rectal Electrode with Recurrent Irrigator.

The negative pole is attached to the irrigator, the positive to the sponge. Treatment should be given for five to thirty minutes, depending on the indications. This method is excellent for atonic constipation and for intestinal paresis. The writer has had good results in the latter, employing it as an adjunct to other treatment. For such condition prolonged application is required. The faradic current is preferable—as strong as the patient can bear with comfort. The galvanic may be used with a current of ten to fifteen milliampères.

Proctoclysis.—Proctoclysis, or the injection of physiological saline solution into the rectum by the drop method, was first suggested by Dr. John B. Murphy of Chicago. This procedure is of special value in *sepsis* and *postoperative thirst* and is of use as an adjunct to other treatment in postoperative shock, hemorrhage, intestinal paresis, and uremia. In my experience more active treatment, the employment of continuous (recurrent) irrigation at 120° F. for a prolonged period—an hour at a time several times within twelve hours is more efficacious in shock, uremia, and intestinal paresis—followed by proctoclysis as an adjunct during the intermission periods.

One of the difficulties which the physician must endeaver to overcome in the administration of saline solution by proctoclysis is the maintenance of a constant temperature of the solution. The application of hot water bags or hot towels to the fountain syringe and connecting tube and the insertion of the hot electric bulb in the solution are well-known devices. Elbrecht's apparatus necessitates a special heating chamber in addition to the containing reservoir, with the employment of an electric heater, an alcohol lamp or a Bunsen burner. The method though scientific seems complicated and is quite expensive. There are many other devices.

The writer in August, 1909, was the first to report the use of the vacuum bottle for proctoclysis.[5] It has a specially devised attachment, and has proved efficacious in preserving the saline solution at a constant temperature. Subsequently other adaptations of the vacuum bottle for proctoclysis were reported, one of them being almost a fac-simile of my own. No reference was made to the author's pre-existing instrument, until he called the publisher's attention to the fact.

The heat-retaining proctoclysis bottle is readily understood from the illustration (Fig. 2067). *A* represents a thermos or vacuum bottle; *S* is the suspending sling. Through the screw-cap *B* which closes the bottle passes a small conducting tube of metal or hard rubber to which is attached the outflow tube *F*. Parallel with this conducting tube is the filiform tube *C* which allows the entrance of a fine column of air, so as to render the flow possible. This last tube passes through the solution to within about one-eighth inch from the bottom of the bottle. As the instrument is employed inverted, it would correspond to the same distance from the top of the bottle. This filiform tube can be covered with hard rubber externally where exposed to the air, as a non-conductor. The part lying within the bottle is purposely made of metal so that it is rapidly heated by the surrounding solution and the entering air is thus in turn markedly heated.

A series of experiments have demonstrated that there is a loss of only 1° to 2° F. in the temperature of the solution in the bottle during the administration of proctoclysis (the drop method) lasting half an hour—a negligible amount. The screw compression valve *D* is applied close to the bottle attachment, so to avoid as much as possible the solution cooling in the soft outflow tube. At *E* there is a tube for the escape of flatus. This is furnished with a stopcock. The tube runs to the level of the top of the bottle where it is suspended by a hook. The tube for flatus can thus be opened at any time without interference with the flow. Ordinarily, however, its stopcock is kept closed. Formerly the container was lowered when flatus occurred, or a T tube was inserted between the catheter and outflow tube for its escape.

The outflow tube is joined to the catheter *H* by a short piece of glass tubing *G* for the purpose of observing whether the flow is constant. The glass tube can be covered with a small piece of asbestos packing, or the catheter can be drawn up over it; or it can be pushed further into the asbestos-covered tube.

An asbestos tube surrounds the conducting tube from its junction at the bottle to the catheter except at the narrow area compressed by the clip. This lessens the dissipation of heat and obviates the use of hot towels. The asbestos tube passes up the flatus exit tube as far as the stopcock.

The catheter *H* for rectal injection passes through a self-retaining rectal tip *I* and the former can be inserted to any length desired. The conducting tube *F* is especially thick as in Elbrecht's apparatus.

The vacuum bottle is filled in the usual manner and the cork with special attachment inserted and the cap screwed on. The bottle is then inverted and suspended in a cord sling *S* as in the illustration.

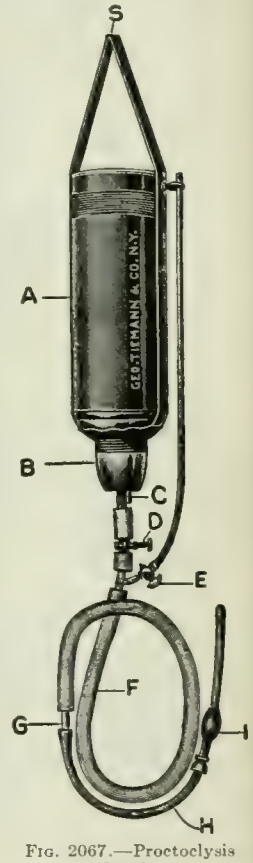

Fig. 2067.—Proctoclysis Bottle.

A small amount of fluid will escape from the bottle by the filiform air tube until the solution reaches the level of this tube, which now lies near the top of the bottle. The bottle is then suspended about six inches to a foot above the rectum or higher if desired and the flow tested for the desired speed before inserting the retaining rectal tip and catheter. As already stated, there is practically no loss of heat in the container, all of it occurring during the passage of the drops

through the outflow tube; the slower the speed, the greater the loss. It is remarkable how great this may be at the slow speed. Careful thermometric tests were made and the following table is furnished with each instrument:

Temperature of water in bottle.	Length of tube (in inches).	Number of drops per minute.	Final temperature in rectum.
190° F.	30	60	115° F.
160° F.	30	20 or less	100° F.
150° F.	30	40 to 50	100° F.
138 to 140° F.	30	150 to 200	105 to 110° F.
120° F.	30	200 or more	120° F.

At the start the speed is always more rapid, and, though for example gauged to say fifteen drops per minute, it may in the course of two minutes, drop to five drops per minute. A test of two or three minutes should therefore always be made before inserting the catheter so to insure a constant flow at the desired rate. There is no loss of temperature at a speed of 200 drops or more per minute and at this speed the solution should never be over 120° F. in the bottle. This bottle can be used for enema or recurrent irrigation in shock. It could also be employed for infusion, or to secure a constant temperature for hypodermoclysis.

ROBERT COLEMAN KEMP.

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Enterokinase.—In certain instances digestive fluids are secreted containing incomplete enzymes, or as these bodies have been called, zymogens. Zymogens have no activity until they have been brought under the influence of an activator. The best-known example of a zymogen is contained in the trypsinogen of pancreatic juice. Pancreatic juice collected directly from the pancreatic duct is without influence upon protein. If, however, an extract of intestine is added to the inactive pancreatic juice the proteolytic activity becomes strong. The intestinal extract contains an activator, or as this class of bodies has been called, a kinase, and from its origin enterokinase. During life inactive trypsinogen is transformed to active trypsin on its entrance into the duodenum. Little is known concerning the nature of enterokinase, but since its action is stopped by heat it has been classed as an enzyme.

FRANK P. UNDERHILL.

Enterolithiasis.—Enteroliths (intestinal stones) are as a rule small concretions which consist in the greater part of inorganic matter. They are usually round, firm, and heavy, and are almost entirely composed of ammoniomagnesium phosphate (triple phosphate) arranged in concentric strata around a nucleus generally formed by some indigestible material derived from the food.

There is another variety of intestinal concretions, light, irregularly-shaped, which cannot be classed as belonging to the genuine enteroliths. These concretions are partly porous and consist of organic substances incrusted with inorganic salts, such as ammoniomagnesium phosphate, calcium phosphate and carbonate, and magnesium phosphate and carbonate. The avenoliths "oat-grit stones" belong to the latter class, also incrusted hair-balls, and some of the smaller incrusted coproliths have perhaps been counted among these spurious intestinal concretions. The sclerenchymatous cell-derivatives, so abundant in the flesh of certain varieties of pears, are also apt to appear in the form of spurious intestinal concretions.

Most of the small, hard concretions usually designated as intestinal gravel or sand are not of a genuine enterolithic character. They are discharged in large amounts—occasionally a teaspoonful at a time—are sometimes hollow or shell-like in appearance, and are composed of ammoniomagnesium phosphate, calcium carbonate, and organic material. The granules represent incrustations of earthy salts upon vegetable débris that has resisted the influence of the digestive juices. They feel quite coarse to the touch and leave but from two to three per cent. of inorganic residue on incineration. Pear-sand is the most frequent of all intestinal sands. Its microscopical appearance is quite characteristic. According to Duckworth and Garrod the granules, when examined under low power, appear as if studded with projecting crystals, and, after removal of the inorganic incrustation by an acid, they are seen to be composed of woody cells whose thick transparent walls are traversed by channels running from the narrow cell-cavities toward the surface.

True intestinal sand, on the other hand, shows no vegetable basis and no rigid skeleton. Its main characteristics are hardness and grittiness which are due to its large content of inorganic salts. The masses exhibit generally a dark-yellow, reddish-brown, or green color, occasionally admixed with pale particles, and are soluble in boiling nitric acid and insoluble in cold potassic hydrate. Most analyses of intestinal sand show about thirty per cent. of organic matter. This evinces that most specimens of enteric gravel submitted to chemical examination belonged to the spurious variety. Genuine intestinal sand has a composition similar to the following, which is that of a genuine enteric concretion in a horse:

	PER CENT.
Triple phosphate	90.0
Organic constituents	3.2
Silica	5.2
Earthy salts	4.2
Ferric oxide	1.0
Sodic chloride	0.5
Sulphric acid	0.5
Soda	0.4
Lime	0.2
Phosphoric acid	0.2

In some of the cases of intestinal sand or concretions there is found a small amount of coloring matter, but there is no evidence that this is derived from biliary pigment in every instance. In others, especially such from herbivorous animals, two peculiar components are occasionally met with which have been described as lithofellic ($C_2OH_{36}O_4$) and bezoardic ($C_{14}H_6O_8+2H_2O$) acids, respectively.

It is possible that in exceptional instances the massing together of this intestinal sand may give rise to enteric concretions. However, as has already been stated, an enterolith is generally built up around a nucleus formed by a foreign substance, and it is hardly conceivable that the heavy and dense intestinal calculus with its arrangement of concentric layers of inorganic material should result from an accumulation of granular units. The opposite, that the intestinal gravel or sand originated from the crumbling of enteroliths is at once precluded on account of the firmness of the latter and an equal hardness of the granules. As a matter of fact, a true enterolith is a concretion which is neither affected by the digestive fluids nor broken up or dissolved by a chemical agent that would not mortally injure the organism.

On the other hand, it is quite possible that the

spurious intestinal sand with its large content of organic matter may at times be derived from the light and porous concretions containing a quantity of lignified cellular material.

There is a third variety of intestinal calculi which may attain considerable size. It is produced by the long-continued medicinal employment of earthy substances such as calcium carbonate, calcined magnesia, and magnesium carbonate. They are, of course, not genuine enteroliths, but may be formed in the same locations and call forth similar symptoms as these. Such concretions may be readily demonstrated by means of the Röntgen rays.

There are still other non-genuine enteric concretions which, contrary to the last, are usually small in caliber. These calculi consist of calcium and magnesium soaps and are produced in the bowel when there is a surplus of ingested fat.

Intestinal stones and granules may be mistaken for biliary or pancreatic concretions. From biliary calculi they may be differentiated by their extreme firmness, high density, and absence of bile pigments and cholesterin; from pancreatic concrements by their firmness, density, their general uniform appearance, and their larger numbers.

A more thorough and systematic study of the stools in abdominal disease has demonstrated the relative frequency of both the general and spurious varieties of intestinal concretions, the contention of Ewald, who has never seen an enterolith that could be distinguished from a coprolith, notwithstanding. While we possess very few definite facts about the origin of enteric stones, we know that they are formed by inspissation and incrustation of ingested material in such parts of the intestinal tract in which normally even there is a slowing of the onward passage of the fecal masses. Intestinal locations facilitating the development of concretions are the saccules of the colon, the cecum, the appendix, and the folds of the rectum. Apparently the small intestine does not furnish the diverticula necessary for the lodgment of the enterolithic nucleus and the subsequent process of incrustation.

The most frequent seat of the formation of intestinal calculi is probably the atonic cecum in which the conditions for their production are very favorable. To the cecal formation and lodgment of these concretions point (1) the atonic sensitive cecum in the presence of enteric lithiasis; (2) the paroxysmal pains lasting for several hours, and emanating from the site of the cecum; (3) the not infrequent occurrence of the concrements in the appendix, giving rise, as some authors maintain, to appendicitis; (4) the coexistence of typhlomyxorrhea in a large proportion of instances of enterolithiasis; (5) the alternating constipation and diarrhea in some cases; (6) the absence or deficiency of unaltered bile-pigment in the enterolithic material and the occasional abundance therein of urobilin, *i.e.* the already far-advanced conversion of the bile-pigment into urobilin, indicating the caput coli as the site where the transformation has taken place; and (7) the occurrence of two-thirds of the cases in women, who are peculiarly predisposed to cecal disease. Furthermore, as the clinical symptoms of enterolithiasis are the same as those of one or the other affection of the cecum, I propose the term "Typhlolithiasis" to signify true intestinal calculi and the most frequent site of their formation.

Intestinal concretions are less the cause than the result of disease, and it is still a mooted question whether or not (with the possible exception of appendicitis) they of themselves occasion clinical phenomena of an important nature. The occurrence of these calculi, on the other hand, always suggests an affection of the large intestine, especially the cecum, to which the treatment should be directed.

HEINRICH STERN.

Enteroptosis.—See *Splanchnoptosis*.

Enterospasm.—The term "enterospasm" designates in brief a tetanic contraction of the intestine, whereby it is converted into a hard cord, and peristalsis is suspended. Peristalsis is normally produced by alternating contraction of the longitudinal and circular musculature of the intestine. But, under certain pathological conditions of the intestine, the contraction of the longitudinal and circular musculature is simultaneous, and upon this fact depends the occurrence of enterospasm. The effect of the spasm is a narrowing of the intestinal lumen, which in severe cases may lead to a disappearance of the same. The spasm may be distributed over the greater part of the intestine, or limited to a small portion of it, thus causing varying clinical pictures.

ETIOLOGY.—The simultaneous contraction of the longitudinal and circular musculature of the intestine in entero-spasm is due to the abnormal irritability of the peristaltic movement of the intestine. In the majority of cases this abnormal irritability is of a purely functional character; hence, neurasthenics and those afflicted with hysteria are the most likely to suffer from enterospasm. In every instance in which stenosis, inflammation of the intestines, or anatomical changes can be excluded from the diagnosis, enterospasm may be regarded as a simple neurosis. Furthermore, enterospasm may also occur as a reflex neurosis when the irritation proceeding from diseased neighboring organs is transmitted to the peristalsis of the intestine. This is especially the case in affections of the uterus and its adnexa. Laborde records several interesting cases of this description. Among other causes of enterospasm we may enumerate meningitis and chronic lead poisoning. Here also the simultaneous contraction of the longitudinal and circular musculature of the intestines may be traced back to reflex action by means of the nerves. Disturbances of innervation of the peristaltic motion of the intestines may be caused by catarrh and other inflammatory conditions of the intestine (typhlitis, appendicitis, typhlomyxorrhea, etc.); and finally also by ascarides and other foreign bodies.

The etiology of enterospasm permits us therefore to recognize two causes as prominent factors of the disease. In one portion of the cases the intestine is perfectly normal, at least no anatomical changes are apparent which could account for the spasm of the organ. In another set of cases distinct causes present themselves which may either be designated as anatomical changes in the intestine, or are due to the irritation called forth by some foreign body in the intestine. There can be no doubt that enterospasm may occur as a pure neurosis. The dominating influence of the nerves on the most diverse conditions and functions of the intestines is not questioned by any author. Hence, it must be granted that purely functional disturbances of peristalsis, even if they induce cramp, are quite as possible as, for instance, the so-called "diarrhea of fear." If the abnormal frequently imaginary sensations of the neurasthenic and the hysteria patient are often capable of inducing the most serious clinical symptoms, why should they not produce a similar effect when they occur in the intestine? In any case, we must agree with Reed when he says that the general practitioner rarely, if ever, meets with a case from purely nervous causes. He adds, that in so-called "functional enterospasm" the cases are partly due to chronic lead poisoning, which is not recognized as such owing to the fact that good care of the teeth and mouth have often obliterated the "lead streak." Rosenheim and other authors also admit that enterospasm of a purely nervous origin is an extremely rare occurrence. They agree, however, that in a majority of cases, it is a question of a combination of functional and organic causes, so that it is difficult to decide which factors play the most prominent part in producing intestinal spasm.

It has probably never occurred that the entire length of the intestine was contracted by spasm; at least, there is no mention of it in literature. But large sections of the gut may be affected by spasm, the large intestine being more prone to it than the small intestine. This is probably due to the fact that such occurrences as inflammation, foreign bodies, etc., are more often present in the large than in the small intestine, and favor a spasmodic contraction. Schütz observed a case of enterospasm in a tabetic patient, in whom the greater part of the small and large bowels were affected, so that they felt as hard as a bone. It has been shown, and we must not forget the fact that intestinal cramp, even when anatomical changes are lacking, may endure for days, even weeks at a time, and we may also point out that women are more frequently affected with enterospasm than men. As regards the clinical symptoms there is no appreciable difference whether the intestinal spasm is due to functional or organic causes, whether it is an independent primary symptom, or whether it plays a secondary rôle as a symptom of intestinal disease, especially enteritis.

Symptoms.—In enterospasm peristalsis is suspended and the intestinal lumen is frequently contracted to such a degree as to render it impassable. The immediate result of intestinal spasm therefore is obstinate constipation, which causes the patient much suffering. Sometimes it happens that mucus or blood is discharged without any apparent cause therefor being discovered in the intestine. Pain is felt in the umbilical region which not infrequently suggests appendicitis, but usually disappears after defecation. This rarely occurs all at once, but by degrees and at longer or shorter intervals. Occasionally stenosis due to the spasm is so great that fecal vomiting occurs, as in ileus. As regards the shape of the feces in enterospasm, what has been said under "Typhlospasm" (see article Cecum) also applies here. There is no characteristic shape of the feces in enterospasm. The pencil-shaped, often canaliculated fecal masses, and those resembling goat or sheep manure attain their respective forms when passing through the sphincters; these may, or may not, be in spastic contraction when there is a spasm of other portions of the intestine. Still, there may be a sphincteral spasm without a synchronous spasm in the intestine. At any rate, enterospasm cannot be diagnosed from the shape of the feces.

The characteristic symptom of enterospasm is the asymmetry of the lower abdomen which in conformity with the course of the cramp assumes a boat shape (boat-belly), and in other portions of the abdomen distinct bulging may be observed. The portions of the intestine lying above the constriction are in a condition of atony and are full of gas and fecal matter. They are inflated in contradistinction to the contracted portion of the intestine. The boat-shaped contraction, according to Reed, is most marked in enterospasm in the course of meningitis and lead-poisoning; it is less clearly marked in intestinal cramp of nervous origin. According to Singer and Holzknecht, in spasm of the small intestine the depression in the contracted portion and the corresponding inflation above this point are not so distinctly apparent. Reed also says that in cases dependent on meningitis there is nearly always at least a slight rise of temperature. The same author has also observed that the abdominal walls are hyperemic in most instances of enterospasm. If the large intestine alone is affected it gives the effect of a cord on palpation. If the stenotic condition has its seat in the rectum it may be recognized by the firm compression of the palpating finger as well as by the difficulty encountered when passing a bougie or the tube of an irrigator through it. In spastic obstipation hypermotility of the upper sections of the intestine is a marked feature which, as evidenced by the Roentgen ray, causes a more rapid onward passage of the bismuth meal. In making a differential diagnosis the following must be drawn into consideration. In the differentiation from peritonitis one should bear in mind that palpation of the large intestine is painful in enterospasm, while the remaining portions of the abdominal wall are not sensitive. In the differentiation from inflammatory changes in the colon one should remember that the inflamed large intestine is swollen and when contracted by spasm is shrunken. On the other hand, the differential diagnosis between primary (purely functional) and secondary spasmodic stenosis may be difficult, even impossible unless direct inspection of the large intestine by means of the colonoscope, electric transillumination or x-ray examination, the presence of chronic appendicitis or some other organic disease is either established or excluded. According to Holzknecht, radiography is the most reliable diagnostic agent; it permits the differentiation between a spasmodic contraction of the intestine from a condition of organic stenosis.

Treatment.—The treatment of enterospasm must first of all endeavor to alleviate the cramp, but not to bring about defecation. Cathartics are not only useless, but tend to aggravate the spasticity. As soon as the cramp has subsided defecation will follow of itself. One must clearly understand that in obstipation of long standing great quantities of food and gas have collected which, in consequence of increased peristalsis, as induced by cathartics, are only forced against the stenotic portion, without being able to pass through it. If, on the other hand, by the use of atropine, hyoscine, or one of the opium preparations the intestinal musculature is temporarily paralyzed, thus alleviating the spasm, the passage becomes again patent, and in order to insure a rapid and thorough evacuation of the bowels it is only necessary to administer rectal injections of warm water or olive oil. Massage is also contraindicated in enterospasm as such an active measure tends to increase the tetanic contraction of the intestine. The same must be said of electricity. Rest in bed is imperative; a non-irritating diet should be pursued for a certain period, and warm baths, heat to the abdomen, either by compresses or the electric heating pad, may be found of service during an enterospasm. The dilatation of the rectum by means of bougies has also some advocates.

In secondary (symptomatic) spasmodic stenosis of the intestine the treatment should be directed toward removal of the underlying cause, whether it be a renal or gallstone colic, chronic appendicitis, cecal disturbances, etc. In case there are incarcerated coproliths or foreign substances that cannot be dislodged by ordinary means, or animal parasites that cannot be exterminated by anthelmintics, operative measures for their removal should be resorted to as was done in the cases described by Schaal and Kiesselbach.

Heinrich Stern.

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Entoderm, also called entoblast, and occasionally hypoblast, is the innermost layer of cells in the embryo; it is an epithelium which, in the adult, lines the digestive canal and its appendages, lungs, liver, pancreas, etc. (See *Germ Layers.*) C. S. M.

Entomostraca.—The subclass of crustaceans which includes the more primitive types. They are usually small species with a variable number of metameres. *Cyclops*, *Daphnia*, and *Diaptomus* are common genera. Some of these animals serve as intermediate hosts for certain parasites, such as round worms. A. S. P.

Entropion.—See *Eyelids*.

Enuresis is a condition in which the urine is passed involuntarily or unconsciously. It is not so much a disease as a symptom common to many diseases and disorders. In childhood, however, it may be considered a separate malady, since it is often found at this age without any other accompanying symptom or lesion; in infants, up to about three years of age, it is physiological.

Mechanism.—The bladder is a fibromuscular sac which acts as a temporary reservoir for the urine. The urine does not normally escape as it falls into the bladder, and without the knowledge of the individual; but, slowly and constantly secreted, it gradually accumulates in the bladder until it can be expelled. It is retained in the bladder by the sphincter vesicæ; it is expelled by the muscular contraction of the coats of the bladder and the detrusor urinæ, assisted by the diaphragm and abdominal muscles. Normal micturition is a reflex act. As the urine gradually flows into the bladder the intravesical pressure increases, until, on a sufficient quantity being present, afferent impulses are sent from the bladder to the center for micturition in the lumbar enlargement of the spinal cord; from this efferent impulses are sent down strengthening the inhibitory force at the neck of the bladder, and thus causing delay in the act of urination. Further, there exist a motor tract and an inhibitory tract from the brain to the center in the cord; and, as the intravesical tension continues to rise, impulses are sent to the brain, and other impulses, now conscious, are remitted to the neck of the bladder, causing either relaxation or further tightening till a suitable time and place present themselves. The act of urination is then brought about by the relaxation of the sphincter and the combined action of the detrusor urinæ and the abdominal muscles. Any interference with this mechanism may cause enuresis.

Etiology.—This is frequently obscure, and many conditions that are considered causes are often probably only coexisting and not causal.

Any interference with the normal mechanism of micturition, as given above, will cause enuresis; such interference can take place at the lumbar center, or in the afferent or efferent nerve tracts, or in the brain. Other causes are: 1. In the urine: increase in quantity or acidity. 2. In the bladder: malformation, increased irritability, muscular spasm of the detrusor urinæ, non-development or imperfect innervation of the sphincter vesicæ, calculus. 3. In the penis: phimosis, paraphimosis, elongated or adherent prepuce, balanitis. 4. Stricture of urethra and enlarged prostate in advanced age. 5. Fissure or eczema of anus, and worms. 6. Lesions of the nervous system—shock, hysteria, locomotor ataxia, apoplexy.

Recently the suggestion has been made that enuresis is due to a deficiency in the secretion of the thyroid gland, and on this supposition thyroid extract in half-grain doses has been recommended as a means of cure. If there are other signs of thyroid deficiency this treatment may be of service; but it is probably of little benefit, when the child shows no decided signs of thyroid insufficiency. The treatment, however, may be tried when other measures fail.

In children this distressing condition is generally due to want of development of the muscles of the bladder, chiefly the sphincter vesicæ, and to lack of proper training. It must be remembered that up to about three years of age enuresis is physiological, and that after that age proper education can do much toward inculcating good habits. Often, too, there may be a diminished sensibility of the nerves of the bladder, when the sensations are not sufficiently strong to awaken the patient, or else the sleep is abnormally deep and prolonged. Children with a neurotic tendency are often afflicted with enuresis. The trouble generally disappears at or about puberty.

Symptoms.—Enuresis may be mistaken for the "overflow" or retention of urine common in enlarged prostate, but a catheter will settle the diagnosis. Otherwise the diagnosis is clear from the statement of the patient or parent.

In children the disease is classified as (1) enuresis nocturna, (2) enuresis diurna, and (3) enuresis continua. Of these the commonest is the nocturnal variety, in which the patient is troubled only at night, but regularly every night, and this in spite of the fact that he has emptied his bladder before being put to bed. The child is apt to be gloomy and downcast, and apparently much troubled about this sad condition which is indeed his misfortune and not his fault. In some cases the trouble continues even when the patient is aroused every few hours.

The diurnal variety is caused by muscular contraction, chiefly in laughing and coughing, and is apt to persist longer than enuresis nocturna; when found after the age of puberty it is more commonin woman.

Treatment.—Whenever possible remove the cause or apparent cause. Look after the general condition of the patient. In this connection it may be well to remember to look for adenoids and enlarged tonsils. In the case of children punishment and reproaches are reprehensible; the little patient probably suffers considerably from the knowledge of his affliction. Many remedies have been tried, some with a little success. Raising the foot of the bed, so that the urine does not rest on the base of the bladder, has been recommended; so, too, has electricity—the faradic current—one electrode in the rectum, the other on the perineum. Highly seasoned food, which may prove irritating, should be prohibited; and the amount of fluid ingested, particularly in the afternoon and evening, should be reduced.

Drug medication is largely empirical, but cures have been reported from the use of strychnine, fluidextract of ergot, iron, atropine; also nitrate of silver applied locally. Of these atropine has probably proved of most service. One grain of atropine sulphate is put in two ounces of distilled water; the dosage may be commenced at one or two drops, and increased one drop at a time until the patient shows flushing of the face and neck in about twenty minutes after the administration of the drug. The dose is then diminished one drop, and is continued at this amount as long as necessary.

In the *Medical and Surgical Reporter* for March, 1898, is reported the case of a boy who by mistake took, four times a day, a pill of extr. cannabis indica, gr. $\frac{1}{4}$; hyoscyamine, gr. $\frac{1}{100}$; zinc phosphide, gr. $\frac{1}{8}$; and was" cured," in three days, of enuresis.

R. J. E. Scott.

Enzymes.—These are substances that bring about chemical reactions by their presence without being used up materially or entering into the reaction; in other words, they act by catalysis and for a long time they have been included among the catalytic substances. To the enzymes is applied a specific terminology. The substance upon which an enzyme acts is called the substrate, and often an enzyme is named for the substrate; thus, lipase acts upon fat, amylase acts upon starch; or, the type of chemical reaction induced

determines the name of the enzyme, as oxidase or reductase, and, finally, an enzyme may be named after the product formed, as alcoholase. In earlier times no uniform system of designation was followed, which accounts for the names, ptyalin, pepsin, trypsin. Nearly all the late additions to the list of enzymes have the termination "ase," with a prefix indicating the type of substrate.

Enzymes in general are of two great classes: (1) those contained in secretions, elaborated by special glands, the extracellular enzymes; and (2) those found only within cells, the intracellular enzymes. The former are relatively easy to obtain, as for example, by collection of the secretion of a specific gland. For the demonstration of the existence of the intracellular enzymes methods must be followed which provide for the crushing of the cells and the pressing out of their contents as a cell juice, or else the enzymes may be extracted from the crushed cells by means of various solvents, as water or glycerine. In whatever way obtained enzymes are strongly contaminated with other substances, especially with proteins. Up to the present time an enzyme has not been isolated in a pure form and its chemical composition and structure are unknown. The enzymes are probably colloids, or at least they cannot be separated from colloidal materials. Many finely divided substances such as kaolin, carbon, infusorial earth, and colloids such as proteins and alumina, possess the property of adsorbing enzymes. By a sufficiently high temperature enzymes lose their specific properties, and certain of them are sensitive to the action of light.

Enzymes are formed within living cells and in certain instances only an incomplete agent is elaborated. These substances are called zymogens and one of the best-known examples of a zymogen is trypsinogen which is not an active enzyme until it has been acted upon by the enterokinase of the intestine. Enterokinase appears to possess enzyme-like characteristics since it is destroyed by heat. In certain other cases, however, the presence of bodies that are not influenced by heat and are dialyzable, and therefore are not enzymes, are essential for the activity of the enzyme. As an instance of this type may be mentioned the necessary presence of hydrochloric acid for the action of pepsin. Certain of these substances are ordinarily called co-enzymes. As they are not to be classed with the enzymes they may be designated more correctly, as activators. Enzyme reactions may be reversible. A true reformation of a substrate once split has not been proven for the proteins or the carbohydrates. Such syntheses do occur, however, of which the following may be cited as an example: Amygdalin is split by maltase into mandelic acid, nitrile glucoside, and dextrose. From these products maltase is capable of synthesizing amygdalin. With fats reversible action has been well established.

Enzymes are very specific in their action, possessing an ability to act only upon certain classes of substances (proteins, carbohydrates, fats). As a rule an enzyme has a very narrow range of activity exerting its influence upon one special type of compound. Enzymes are neither precipitated nor destroyed by many antiseptics, such as toluene, thymol chloroform, etc. The products of enzyme action have a retarding influence upon further activity. They are also markedly influenced by ions and salts. Throughout the body are a variety of enzymes capable of retarding or checking the activity of others. These inhibitory enzymes have been called anti-enzymes, and although they have been studied little it is assumed that they have the power of regulating or controlling enzyme action in the organism.

A partial classification of enzymes follows: Proteases or proteolytic enzymes exert a hydrolytic splitting action on proteins; the most familiar proteoses are pepsin, trypsin, eripsin.

The amylases, or diastases, are capable of transforming starches into maltose or dextrose with dextrins as intermediate products.

Invertases are enzymes formed in the enteric juices capable of transforming disaccharides into monosaccharides, sucrase acting on sucrose and changing it to a mixture of dextrose and levulose (invert sugar), maltase converting maltose to dextrose, lactase transforming lactose to dextrose and galactose.

Lipases act upon fats, splitting them into fatty acids and glycerine. Steapsin, a lipase, is present in pancreatic juice, and lipases are distributed in the tissues generally as intracellular enzymes.

Nucleases are found in the tissues and their action is to decompose nucleic acid to purine bases, phosphorix acid, etc. Oxidases are oxidizing enzymes. They are divisible into three groups, oxygenases, peroxidases, and catalases. The oxygenases and the peroxidases yield oxygen to other substances and then at once reoxidize themselves. Catalases do not reoxidize themselves from the air. Some of the oxidases are aldehydase, which converts salicylaldehyde into salicylic acid; laccase transforms hydroquinone into quinone; tyrosinase changes phenols, naphthols, aminophenols, indophenol, phenolphthalein and similar compounds into substances richer in oxygen. Tyrosinase and laccase convert the aromatic decomposition products of proteins into compounds that gradually grow darker and then become insoluble in the animal or vegetable fluids. There is probably a relationship between the presence of a tyrosinase and the occurence of homogentisic acid in the case of alkaptonuria. In this condition the urine turns dark on exposure to air.

Coagulases are clotting enzymes and include thrombase or thrombin, which coagulates blood, and rennin which clots milk.

Reductases, or reducing enzymes, are capable of causing a reaction whereby a chemical reduction occurs, as for example, the formation of hydrogen sulphide from sulphur.

Autolytic enzymes are found in the tissues generally and are capable of transforming tissue constituents into characteristic cleavage products.

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Ephedra Antisyphilitica.—*Mountain Rush, Canutillo, Mormon Tea, Grease Wood, Whorehouse Tea.* The twigs of *Ephedra antisyphilitica* C. A. Meyer (fam. *Gnetaceæ*). This peculiar shrub, and various other species of the genus used similarly, are found in great abundance over the arid regions of our great plains. The plant reaches a height of two or three feet and produces a dense mass of erect, green, leafless branches, half the thickness of a lead-pencil and striate or channelled, with membranaceous scales at the joints. Wherever it is known, it bears a high repute in the treatment of veneral diseases, which are seldom differentiated in the reports. It is both bitter and astringent. The latter property might give it some value in gonorrhea, while the former would render it tonic and perhaps alterative. No systematic study of its properties has been made, and we can only conclude that it probably has some merit. It is chiefly given in decoction; the dose employed representing one to two drams of the drug. The remedy may also be administered in the form of a fluid extract. The drug contains a glucoside, *ephedrin*. *E. monostachye* L., of Asia, has a similar reputation.

HENRY H. RUSBY.

Ephedrine.—An alkaloid ($C_{10}H_{15}NO$) derived from *Ephedra vulgaris* Rich. and *E. helvetica* C. A. Meyer. It is crystalline, colorless, and soluble in alcohol. It is used in the form of the hydrochloride, which is soluble in water. It is poisonous, resembling atropine in some respects. While it lowers the blood pressure, it causes the temperature to rise and the pupil to dilate. It is used like atropine for the latter purpose, one to two minims of the ten-per-cent. aqueous solution being instilled. It usually requires nearly an hour to obtain the desired effect, but when once obtained it usually lasts for from a half a day to one day, but accommodation is not affected.

Pseudo-ephedrine, has the same composition as the above and its hydrochloride has the same properties and is used in the same way. HENRY H. RUSBY.

Ephelis.—See *Lentigo*.

Ephrata Springs.—Lancaster County, Pennsylvania.

POST-OFFICE.—Ephrata. Hotel and cottages.

ACCESS.—Via Reading Railroad. Lititz, an old Moravian settlement, is 7 miles distant; Reading, 19; Lancaster, 14; and Wernersville, 11 miles.

This pleasant resort is located on the western slope of the Ephrata Mountain, one of the highest points of land in Lancaster County. Many charming features of climate and scenery are united here. The visitor will find pure air, a comfortable and well-kept hotel, excellent fishing, and delightful surroundings The water of the Mountain Springs is celebrated for its purity and sparkle. The springs discharge about three thousand gallons per hour.

The following analyses have been made of three of the springs:

ONE UNITED STATES GALLON CONTAINS.

Solids.	Grains.		
Silica	0.555	1.518	1.022
Iron and aluminum oxide	0.146	0.088	0.093
Calcium carbonate	0.642	4.868	0.730
Magnesium carbonate	0.133	1.482	0.300
Calcium sulphate	None	0.803	None
Sodium-potassium chlorides	0.335	Trace	0.335
Sodium-potassium carbonates	1.693	0.208	1.365
	3.504	8.967	3.845

Various amusements, among them bowling and tennis, are provided for the guests.

EMMA E. WALKER.

Epicarin is a condensation product of beta-naphthol with cresylic acid. It is a non-corrosive antiseptic, and has been used as a five to ten per cent. ointment with lanolin as a base in various skin diseases such as scabies and prurigo.

R. J. E. SCOTT.

Epidemiology.—This term (from ἐπί, on, δῆμος, people, and -ology, the science of) denotes the science which deals with the study of the causes of outbreaks of disease among human beings, the factors which contribute to their spread and continuance, and the evolution of the principles for their control and eradication. It deals with the diseases of human beings in contradistinction to epizoology, which has to do with the diseases of the lower animals. Formerly restricted to those diseases which occurred in epidemic form, at present it comprehends the study of any disease regardless of its character. It is not limited to contagious, infectious or communicable diseases, but may be applied to any disease of mankind. It bears an intimate relation to the other sciences because, as may be readily seen, biology, bacteriology zoology, pathology, chemistry, geology, mathematics, hygiene, and the various branches of medicine, must of necessity be drawn upon by a science which bears such an intimate relation to every activity of human life.

Epidemiological studies consider every factor regarding a disease, taking into consideration everything which may have any possible bearing upon its production, spread, or continuance. In this way the sources of infection, if they exist, are discovered, and if the disease be one of deprivation, or poisoning, a careful study of the dietary of persons attacked may throw light upon the way in which the disease is produced.

The diseases of man may be roughly divided into three general classes: (*a*) Those which are caused by living organisms. (*b*) Those which are caused by the ingestion of deleterious chemical substances, or by the absence in the dietary of necessary constituents. (*c*) Those which are mental in character.

In the first may be placed those diseases in which the infecting agent has been definitely proven to exist, or in which its existence may be suspected with a reasonable degree of assurance.

Under the second heading are placed those diseases which are caused by taking harmful substances into the body, and those diseases in which some necessary constituent has been omitted from the dietary.

In the third class may be placed those diseases which are produced by faulty mental habits.

The sources of infection for the living organisms of disease are man, the lower members of the animal kingdom, and the human environment. Of these, the most important is man himself. Most of the communicable diseases from which man suffers are peculiar to man himself. The environment, except as it is affected by man or the lower animals, has relatively little to do with human infection. The lower animals play a rôle in the production of certain diseases as media of convection. Those which carry diseases to man are chiefly the domestic animals, and in such instances these lower members of the animal kingdom would not carry disease were they not infected by man himself. For example, cats spread ringworm, dogs, rabies; horses, tetanus; goats, malta fever; cattle, anthrax; hogs, trichiniasis; rats, bubonic plague; flies carry typhoid fever; ticks disseminate Rocky Mountain spotted fever; lice carry typhus; a domestic mosquito (Stegomyia calopus) carries yellow fever, and bedbugs transmit kala azar. Water, soil, air, and food, are media for disease transmission when infected by man himself, or in certain instances by the lower animals.

The causal organisms of human disease are of two general varieties—vegetable and animal. These produce derangements of the human mechanism by local destruction, by the evolution of toxins, and by mechanical interference. In the study of causal organisms, epidemiology endeavors to determine their developmental cycle, if there be one, their mode of transference from the sick to the well, the rôle which is played by intermediate hosts, and the period of incubation of the parasite in either the autosite or the intermediate host. It is equally important that knowledge be had of the portals of entry and exit of the infecting agent, and the factors of individual or racial susceptibility or immunity to the disease under consideration. The rôles of fatigue, exposure, deprivation, excesses, vitiated atmosphere, and concomitant diseases also require study. In fact, it may be stated that in epidemiological investigations every factor of life, either of the individual or the nation, and every element of the environment, whether at home or at work, require careful study in their bearing upon food, air, soil, water, and fomites. Therefore

in the study of a given disease no fact bearing upon the life habits of those attacked is too trivial to merit the most careful consideration.

The accuracy of the diagnosis is most important because without this there is no proper starting point for the investigation. It is probable that there are many diseases whose origin and mode of causation are to-day unknown simply because we have not clearly differentiated them as disease entities. This is essential because epidemiology in its final analysis endeavors to lay down the principles which govern the control of human disease. Once the basic facts have been discovered, the evolution of control measures is relatively simple.

In a short article it is only possible to give the headings under which this science is considered. The reader desiring further and more detailed information is referred to the various handbooks on hygiene, sanitation, and general medicine. It may be stated, however, that there is at present no complete work on the subject, indeed, its proper consideration would require several volumes.

The general factors of epidemiology find their primary basis in the study of the sick person himself and secondarily in the study of his environment, including the lower members of the animal kingdom therein.

On account of the variance in the anatomical construction and the physiological processes at the different life periods, it is found that certain diseases have a higher rate of incidence at certain ages than at others. Age also affects the environment, occupation, and habits of the individual and therefore influences susceptibility or immunity. Many diseases do not occur during the later life periods simply because the individual has suffered from an attack at an earlier age and has acquired an immunity to them. The developmental processes and the wear and tear incident to age also influence the age distribution of certain diseases. The ailments of youth frequently lay the foundation for the diseases of old age and hereditary and acquired hyper- or hyposusceptibility also enter into the problem. Infancy, puberty and adolescence, early adult age, middle age, and old age must therefore be taken into consideration in connection with the subject of the age incidence of disease, each period showing a preponderance of certain diseases.

Sex is of importance, chiefly by reason of the difference of manner of life of the two sexes. The more cleanly habits of woman and her lack of exposure to the weather act in her favor, while indoor occupations tend to the weakening of the disease barriers of her body. Men, on the contrary, are thrown in closer contact with a large number of persons. They are exposed to all sorts of weather and frequently are obliged to take food and water of doubtful purity.

Nationality and race play a rôle in regard to immunity and predisposition largely by reason of the difference in habits of the various races. Habits in this sense is used as including, not only habits of life, but of food and environment.

The epidemiological considerations of occupation are of the utmost importance and form a set of changing conditions which are being altered from day to day and from year to year by the introduction of new methods, improved machinery and the adjustment and readjustment which is constantly taking place between capital and labor. The occupation itself, the wage and the hours of labor comprise a series of variants which serve to modify the statistics of morbidity in their relation to the diseases of occupation. The epidemiologist is not content to know that a given individual is a laborer, machinist or mill ope.ative. He must know exactly what strains a given occupation throws upon the human organism and the diseases to which a certain class of operative is peculiarly liable. The problem of fatigue, the employment of children and women, the exposure to certain infectious or noxious agents all require investigation. The deleterious influences of gases, vapors, atmospheric pressure, high temperature, brilliant lights, metallic poisons, and dusts are all comprehended within the problem. A study of the occupations of persons attacked by a given disease furnishes a clue to the influence which the environment of labor has had upon the production, dissemination, and continuance of that disease. In common with other epidemiological investigations it includes everything which takes place within that environment.

It is equally important that knowledge be had not only of the country in which certain diseases are most likely to occur, but also to know the exact locality and the exact place in that locality in which disease is occurring or from which cases under observation may come. In this connection, it may be pointed out that climate plays a very great rôle in the determination of this point. The heat and moisture of the tropics create a suitable environment for the growth of animal and vegetable parasites and the habits of human life in that zone may tend to render man more liable to their attacks. The cold of the other zones produces overcrowding and the consequently increased opportunities for the interchange of infection bearing secretions. The geographical distribution of the various parasitic life forms also renders residents of certain zones more apt to be exposed to certain diseases. If the infectious organism exists in a given place and the mechanism for its transmission be also there the disease will also exist in that place provided that the infectible material receive the infection. The environment of the home is quite as important from an epidemiological standpoint as that of occupation, because a greater amount of time is spent therein. The factors of the home environment which are of importance are ventilation, drainage, cleanliness, water supply and the presence of disease carriers, the latter including not only human carriers but insect and animal carriers as well. Food may be also considered as a part of home environment and in this connection it may be pointed out that although several different persons may eat at the same table and be served the same food their dietaries may be widely different.

The part which season plays in the distribution of disease is dependent upon the life history of disease vectors and the habits of human life as they are affected by climate.

The lower members of the animal kingdom which act as disease vectors may be regarded as a part of the environment. They may act as mechanical or biological disease transmitters. In the former instance the infecting agent is usually a vegetable. In the latter it is usually an animal parasite. The organism may or may not undergo multiplication within the body of the vector, and in the mechanical form of transmission many different species may perform exactly the same rôle. In the biological form of transmission, the infectious organism usually undergoes a developmental cycle within the body of the intermediate host and in such instances the host is usually obligate.

Human disease carriers are from the epidemiological viewpoint extremely important. The term 'carriers' is generally taken to mean a person who harbors a pathogenic organism and distributes it to others without himself showing any of the signs or symptoms of the disease. There are carriers of vegetable and animal parasites, the former being known as bacillus carriers and the latter as protozoon carriers. Carriers may be acute, chronic, or temporary, and they may transmit infection, either directly or through the intermediation of food or other inanimate objects.

Epidemiology endeavors to discover the caustive agents of a disease. It is also necessary that knowledge be had of the route of entry of the causative

factor, and it is also essential to know the route of exit of that organism from the bodies of the sick. Certain disease organisms may enter the body by many different routes, others by one only. Conversely, in many diseases the infecting agent may be discharged from the body of the sick person by several different exits, and in others by one only. Disease germs may be discharged either passively, as in the case of malaria, or actively, as in the case of typhoid fever. As a rule, those diseases which are received through the gastrointestinal tract are also spread by the discharges from that tract. In those diseases in which the organism is carried by suctorial insects the disease germ is taken from the body through the skin and is received into the body by the same route.

In making an epidemiological study of a given outbreak it is first necessary to obtain a list of the names and addresses of the persons attacked, to determine their age, sex, and marital condition, their place of occupation and the date of onset of the disease in each instance. If the outbreak is a large one the number of cases should be plotted as a curve, the days being arranged as the ordinate and the number of cases as the coordinate. Next should be determined their exposure to a common food supply and the possibility of their contact with other persons having the disease. Their environment of residence and occupation should next be looked into to determine what possible bearing these may have upon the outbreak. If the food or water supply is suspected they should be carefully examined and search made as to the possibilities and means of their contamination. In making such a study no fact however small should be overlooked. Particular attention should be paid to entertainments which the infected persons may have attended. In making a survey of the environment careful search should be made for carriers, either human or animal. Care should also be taken to determine by appropriate means the correct diagnosis in each instance. Careful search should be made for light cases and the possibility of missed cases should also be borne in mind. The method of investigation will, of course, vary with the disease under consideration and what would be necessary in studying an outbreak of a disease carried by mosquitoes might not be necessary in the study of an epidemic, the germ of which is carried in the alvine discharges.

Having determined the character and cause of the outbreak it becomes necessary to apply the knowledge so gained to the eradication of the epidemic. This will, of course, vary with the disease under consideration. In general, it includes the destruction of the infectious agent after it has left the body. The killing of the lower animal vectors and the protection of both the sick and the well from them. In undertaking the destruction of any life species the plan of attack must be carried on along every avenue of their existence. If the vehicle of dissemination is an inanimate object, such as food and water, the infectious agent must be killed therein and the reinfection of this medium for the interchange of pathogenic organisms must be prevented. In those diseases in which the infectious organism is known it may be possible to apply these various measures with accuracy, but in the event that the method of the production of the disease is unknown it may be necessary to apply any or all of these measures in order to control the outbreak. The isolation of the sick from the well and the prevention of their coming into direct or indirect contact is of course essential.

W. C. Rucker.

Epidermin is made by mixing equal parts of melted white wax and powdered acacia, adding the same weight each of water and glycerin while boiling, and stirring until cold. It is used as a vehicle for skin medication. W. A. Bastedo.

Epididymitis.—See *Testes, Diseases of.*

Epilation.—See *Depilatories and Hypertrichosis.*

Epilepsy.*—*Synonyms:* L'Epilepsie, Fallsucht, Epilepsia, Mal caduceo, Morbus herculeus, Falling sickness, Fits.

Definition.—Epilepsy is a chronic disease of the brain characterized by convulsions and loss of consciousness, either one of which may be absent in exceptional instances. There are all possible gradations of the disorder of consciousness, from complete loss to that of complete retention of it. A complete loss of consciousness for a longer or shorter period is the general rule. The muscular spasm of epilepsy is similarly subject to variation, but is much less frequently absent than loss of consciousness. The manifestations of the disease in seizures or attacks have usually been classified according to their severity, such as *grand mal, petit mal,* and *psychic epilepsy.* The first is usually characterized by the severe attack, which ordinarily consists of loss of consciousness and great violence of muscular spasm, while the second is shown in a slight seizure with partial or incomplete loss of consciousness and but slight muscular spasm. Psychic epilepsy is that manifestation of the disease shown in the maximum of mental confusion, and more or less complete loss of consciousness without obvious convulsion.

Varieties.—There are many irregular forms of epilepsy which are often classed as masked, aborted, and partial epilepsy, owing to the imperfect development of the more usual and familiar symptoms. In these masked cases the attack usually takes the form of a more or less transitory mental derangement, without definite motor symptoms. Such an attack is known as a *psychic equivalent* of an ordinary epileptic convulsion.

A number of special names have been applied to epilepsies with reference to their supposed etiology, alcoholic and gastric epilepsy being familar illustrations. Such designations are far from being illuminating and are falling into a deserved disuse.

Symptoms.—The lighter forms of epilepsy, or *petit mal,* usually consist in a momentary loss of consciousness, during which the patient suddenly becomes very pale, while the color first recedes and then suffuses the lips and cheeks, and the respiration is temporarily arrested and then altered in character, or even becomes panting. The eyes remain open, the eyeballs roll upward, and the patient may stare fixedly at some object or into vacancy. When in the midst of some occupation the patient may be taken with this form of attack, there being a temporary suspension of the particular act—the glass or spoon drops from the hand, the pen is arrested in the middle of a word, or trails idly across the page in an illegible scrawl. Oftentimes the patient's trouble is so transitory or slight as to escape the notice of the bystander, and the patient alone may register that an attack has occurred, or, again, he may be unconscious of the fact while it is obvious to others. After such an attack, the patient finishes writing his sentence or picks up the object he has dropped, and beyond a transitory lassitude and mental confusion, nothing reminds him or the observer that anything unusual has occurred. In other cases, or at other times in the same case, the seizure is more severe, both as regards length of loss of consciousness and the severity and extent of muscular spasm. The patient may become rigid (tonic

* Although the text of this article has been entirely rewritten, in its general form and manner of presenting the subject it has followed the article by Dr. A. McLane Hamilton in the former edition of this Handbook, and the author wishes to acknowledge here his indebtedness to Dr. Hamilton for the courtesy thus extended.

spasm), and then become agitated by limited twitchings (clonic spasm). The color leaves the face, and the pupils more or less widely dilate and become unresponsive to light. In a few seconds, however, he is able to rise and go about his business. Many French writers speak of absences, vertigos, and intermediary forms of petit mal, but inasmuch as such attacks occur without obvious spasms, we designate them *psychic seizures*. In this latter class the patient is usually momentarily interrupted in speech, or in the act of writing, as has been already detailed. The head may simply be turned to one side, or there may be but a temporary mental confusion of ideas. The mouth is twisted, the eyes squinted or remain in a meaningless stare. The head may be rapidly jerked about by an irregular spasm of the several muscles of the neck. The chin and head may perform a seemingly purposeful act not unlike one suffering from spasmodic torticollis.

The psychic attacks may consist in only a temporary aphasia, or the temporary abolition of the whole or part of any one of the special senses. The petit mal attacks may exist alone, or, what is more common, be interspersed between grave attacks. Usually the presence of major seizures presupposes the existence of an earlier presence of petit mal or psychic attacks, which close questioning usually reveals. However, there are numerous cases in which light seizures alone exist, or precede for years the graver forms of seizures.

Aura.—The fully developed attacks (grand mal) are, in more than a third of the cases, preceded by certain warnings, or so-called "auræ." These in their order of arrangement as regards frequency and constancy are *sensory*, *psychic*, and *motor*. The sensory auræ of an attack are of the most diverse character, and the patient complains of such transient subjective sensations as tickling or tingling in the skin, chiefly commencing in the ends of the extremities on one or both sides and apparently advancing toward the head from these distal points. Auræ of the trunk and its viscera also exist, the epigastric aura being the most frequent. It consists in a peculiar and disagreeable pressure or sinking sensation in the epigastric region, and ascends to the head. Loss of consciousness succeeds in all auræ when they traverse the extremities or the trunk up to the level of the chin. The patient complains of constriction of the throat, of a sensation as though ants were running, or wind was blowing over the surface of different portions of the body, of fugitive pains, and of a great variety of other sensations. Certain visual warnings are complained of as an immediate precursor of the attack.

The epileptic is occasionally appraised of the coming of an attack by the perception of spots, points of light, or broad and irregular fields of color in which red and blue most commonly predominate. The *visual aura* is usually of such short duration before the fully developed attacks appear that the patient is usually unable fully to describe them. Sometimes the optical illusion is likened to the recession of objects, or their advance, which is largely conditioned on the seeming enlargement or diminution of various objects, or, again, the patient alludes to his being enveloped by a cloud or mist. Patients frequently complain of double vision and of half-vision, which, however, usually indicate a gross brain disease. Less frequent than optical illusions are *auditory hallucinations*, such as rushing sounds, the roaring of waterfalls, ringing of bells, or the whistling of the wind. Many ordinary and actual sounds are perverted in character, diminished, or intensified. More rarely patients complain of auræ of perversion of the sense of smell and taste, which are most frequently seen in those suffering from actual gross brain disease and are too rare to warrant detailed mention here.

Psychical warnings of a more complex character may take the form of murmuring voices which speak imperatively or give commands, and in rare cases a visual hallucination is the immediate precursor. Among the rare auræ may be mentioned a sense of fullness of the bladder or rectum, causing the patient to desire to defecate or urinate. Some patients belch forth large quantities of gas previously swallowed in the momentary mental agitation before seizures occur. The patient in some cases talks unintelligibly, mutters, repeats set phrases, or ejaculates meaningless cries akin to sounds made by certain animals, such as the barking of dogs, the mewing of cats, the bellowing of cows, etc.

There are many premonitory motor auræ such as limited tremblings of the small muscles of the fingers and hands, or twitchings of the facial muscles. Some epileptics present automatic disorders of motility, such as drumming on tables, or tapping the floor with the foot. More complex movements are not infrequently seen, such as movements suggestive of dressing or undressing, or running about in an animated manner. The latter, however, most frequently constitute a part of the real convulsive movement of an attack. Indeed, the motor aura in many instances imperceptibly shades over into the beginnings of the convulsion proper, and in most instances must be considered as a part of the first convulsive movement of the epileptic motor discharge.

A physical or mental state, a true prodrome of an attack, may exist for several days preceding the attack and really constitute a true warning that an attack is pending. There may be an unusual despondency of manner, listlessness, malaise, undue irritability, or forebodings that danger of an attack is imminent. The face is dusky or pale, the eyes injected or of a leaden color, or the temporal vessels stand out rather prominently. More rarely there is a state of unusual vivacity or undue excitement, headache, tremor of the tongue and lips, and various subjective disturbances which in some cases, although very peculiar, are unmistakable to the initiated observer. These prodromes when present are remarkably constant in the individual patient.

Auræ are by no means constant; in fact the majority of patients cannot give a satisfactory account of any special warning. Of 519 cases collected by Delasiauve, of which 229 were personal, but half presented any history of auræ. In my experience but forty per cent. gave the history of anything that could be called a true and distinct prodromal symptom. Gowers' experience, based upon 1,000 cases, is that a special warning "was always absent in 495, while some aura existed, at least occasionally, in 505"; this is a very large showing.

Grand Mal.—The major attacks may be said to consist of three stages, viz., the stage of *tonic convulsion;* the stage of *clonic convulsion;* and the stage of *subsidence* and sleep. The first of these, while most intense, is the shortest and often is insensibly merged into the second. The last stage includes the condition after subsidence of convulsive movement. At the end of this stage the patient either regains consciousness or sinks into a more or less profound sleep.

The attack may or may not be preceded by a warning, but it generally is by a premonitory cry. This, the so-called *epileptic cry*, is not a purely psychic feature; it is loud, shrill, and startling, and while it may be the result of an unconscious cerebral effort or the direct expression of fright, it more frequently is due to mechanical causes, the contracting spasm of muscles of the chest walls forcing the air from the lungs through the unprepared vocal cords. The cry, or more frequently, moan, lasts but a few seconds and is rarely repeated before the actual debut of the convulsion. The patient usually falls or sinks to the ground, rigid and helpless. Hence the popular designation of the disease as "falling sickness." The fall is ordinarily backward, though nearly as frequently the patient falls to one side or forward; the arms are flung out or up in an apparent unconscious

effort to assist the patient to maintain equilibrium. Sometimes the head is thrown back, the forearms and hands being rigidly flexed. When recumbent, the patient may assume a number of positions; most frequently it is a position of pleurothotonos or opisthotonos, the body perhaps being laterally curved one way while the head is drawn in the other direction. The eyes are usually widely opened, the pupils dilated, the whites of the eyeballs well exposed. Often there is some tendency to conjugate deviation, or strabismus. The mouth is firmly closed or opened at the onset of the convulsion and remains so until the end of the first stage. If the onset of the convulsion is sudden and severe, the tongue or lips may be caught between the teeth and in the succeeding clonic convulsion be severely injured by the champing movements of the jaws. The arms and legs may be violently extended, the dorsal surfaces of the hands approximated, and the fingers flexed; the feet overlap each other and the toes are often extended. The abdominal muscles are flatly contracted, and for the moment breathing is suspended. The patient's face, which at first was momentarily pale, becomes livid, and the lips, ears, and nails show a severe grade of cyanosis in consequence of an imperfect oxygenation of the blood. The skin of the hands is purplish, wrinkled, and cold, and all about the mouth is a dusky ring fading off to white at the points where pressure is made against the teeth.

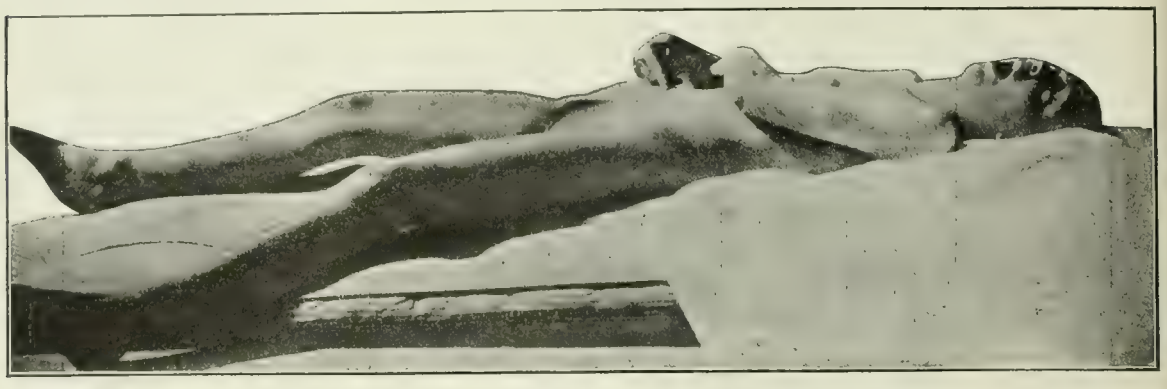

Fig. 2068.—Grand Mal Epileptic Seizure. Onset of the tonic stage.

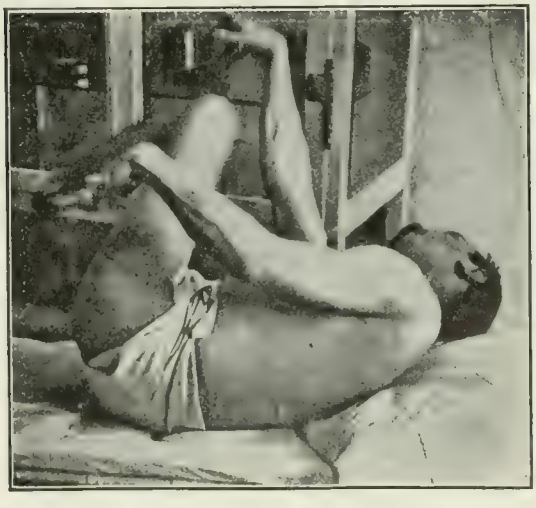

Fig. 2069.—Grand Mal Epileptic Seizure. Tonic Stage at the climax.

The rigidity entailed by the tonic spasm is so great that the exhibition of ordinary force will not enable the observer to overcome the muscular contractions. The intensity of the tonic spasm in different parts of the body often varies considerably. This inequality of rigidity, which may be unilateral, suggests certain more or less definite structural defect in the brain, due either to previous disease, to hemiatrophy, or to traumatism. Sometimes the mouth is drawn to one side, while the head is turned to the other; this result is due to the fact that the cramp of the muscles of one side is distinctly more pronounced than that of the muscles of the other side. The pupils, which have now become fully dilated, are quite insensitive to light, and the cornea to touch. The face is engorged and with such a change the breathing is hurried and noisy. The lips flap loosely with each inspiration and expiration, churning the saliva into a frothy foam which exudes from the mouth. It may also be tinged with blood that comes from a wounded tongue. The movements of a clonic nature now follow, and these may be more or less violent in character but are never as intense as the preceding tonic rigidity. The waves of nerve discharges from the cortex now have a short and infinitesimal rest period between them, during which there may be a partial muscular relaxation which is suddenly reinaugurated by the next discharge into a firm contraction of the muscles; hence a relaxation and contraction succeed each other very rapidly at first in the beginning of the clonic stage, but gradually they widen apart in point of time until the arms and legs, at first agitated only by a sort of fine tremor of tense muscles, are thrown about violently as though convulsed by coarse electric shocks with distinct rest periods between. If the spasm in different parts of the body has been of simultaneous onset, the above description holds good for the whole convulsive picture depicted; but not infrequently, when the convulsion has first begun in one part of the body and extended to other parts later, one side of the body may be in the tonic while the opposite is in the clonic stage. This explanation may also hold for the different segments of a limb, or exceptionally, for the several muscles of a single segment. In this way one understands the convulsive movement as a whole may appear as a sort of "clotted mass of movement," as designated by Hughlings Jackson. In the light of this statement one notes the spasm is disorderly and in no sense rhythmical. In rare instances a generalized tremor may take the place of both the usual types of tonic and clonic convulsions described. Usually such clonic tremors spread from the periphery toward the trunk and grow more intense as they do so. Sometimes the spasm may take on such a character of producing definite flexion and extension of the several joints of the extremities that a kind of incoordination almost purposeful in appearance may be seen. Such

movements, when they occur in an individual who does not fall, produce a gait and general behavior of one intoxicated, of which latter state many patients are often falsely accused by the ignorant. Many times the clonic convulsions, at either their inception or termination, are so severe as to hurl the patient about, or even throw him from the bed upon which he may be lying; and in not a few severe cases it requires the exhibition of much force and ingenuity to prevent the patient from injuring himself by the convulsive violence of the fit. The clonic stage is two or three times the length of the tonic stage in a classic attack, the convulsion as a whole usually seeming much longer than it really is. It is rare for a single attack of epilepsy to last more than three or four minutes, and the great majority are completely over in less than half this time. Frequently, in certain cases there may be fresh accessions of clonic spasm after this stage has seemed nearly over, but ordinarily it is short-lived and the patient gradually becomes quiet, the color returns to the face, and other signs of subsidence follow; the breathing becomes more regular and quiet, the rigidity completely disappears, and the patient lies quite limp; the pulse is more regular and less full, and the patient shifts his position, moves the extremities, or makes movements of the face, especially about the mouth, which are semi-volitional. The head may now be rolled uneasily from side to side, and some effort to rise may be attempted. The patient may open his eyes and look vacantly about, or murmur indistinctly. Sometimes the confusion of ideas which attends the glimmering return to consciousness may manifest itself in incoherent talk and transposition of words.

Fig. 2070.—Grand Mal Epileptic Seizure. The blurred outline of the left arm and upper trunk is due to the beginning of the clonic stage.

During the convulsive stage the patient often has involuntary discharges from the bowels or bladder, caused both by a relaxation of the sphincters and the violence of the contraction of the muscles of the lower part of the abdomen and the involuntary muscles which ordinarily assist in these physiological acts. Rarely seminal emissions may occur. The soiling and wetting of the bed are, in the presence of suspicion of nocturnal attacks, very good diagnostic evidence that a seizure has occurred, especially in adults.

The cutaneous reflexes are lost during the attack, but after the subsidence of the clonic stage we find there is a return and that the deep reflexes are very much exaggerated and usually continue so until the cerebral exhaustion entailed by the attack is recovered from. In some cases, a form of false ankle clonus may be found. Now and then a crossed knee reflex has been reported. The patient gradually regains the normal state, or more commonly sinks into a deep sleep, from which he finally awakens with feelings of exhaustion and headache.

The *temperature* and *pulse* of the epileptic undergo very important changes. In the status epilepticus there is a decided increase in both. The temperature may mount to a great height, 106° or 108°, while the pulse may rise to 180 or 200 per minute. During single attacks the temperature rarely rises more than a half of one degree, while the pulse in the tonic stage is thin, thread like, and not essentially accelerated; during the clonic convulsion it is full and rapid.

The *urine* passed after the attack is found to contain urea and the phosphates in increased amount, indican, and usually a more or less marked trace of albumin. Herter and Smith found that there is often a change in the proportion of sulphates in the urine, the ethereal sulphates being increased to an excessive degree.

A symptom of considerable moment in the diagnosis of true epilepsy is the so-called *epileptic voice sign*. It has been shown and demonstrated by Clark and Scripture[1] that the epileptic individual has a peculiar monotonous, inflexible voice with a marked tendency to drop the same at the end of the sentence. This is said to be constant and of considerable diagnostic moment, especially in the differentiation between true epilepsy and psychogenetic convulsions and hysterical attacks.

Immediate Results of the Attack.—After the attack we sometimes find a variety of disturbances of the nervous system. These are exceedingly variable, and may consist of sensorial or motorial manifestations, and in the former we include the immediate mental derangement. We have already alluded to the headache, which is dull and vertical or frontal. Of course, the injuries the patient may have sustained are quite apt to leave behind their painful effects, but there are disturbances which are connected with the fit itself which are exceedingly annoying. Excessive muscular violence may give rise to fibrillary

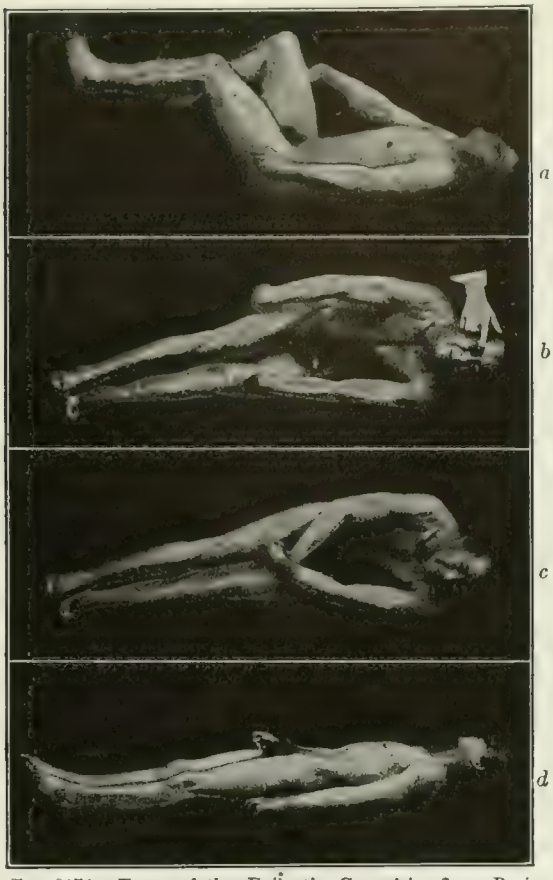

Fig. 2071.—Types of the Epileptic Convulsion.* *a*, Beginning of a generalized fit in an epileptic, who has just fallen backward in the tonic spasm of a seizure; *b*, tonic phase of the fit shown in *a*, further advanced; the spasm has thrown the patient on his left side; *c*, a still more pronounced muscular spasm in the same patient, at the height of the tonic stage; *d*, the same patient in the stuporous or comatose state at the end of the fit.

rupture, and, in rare cases, to dislocation of the large bones.

Spots of cutaneous anesthesia are sometimes complained of, and the skin and conjunctiva are often covered with petechiæ which may coalesce and form a marked hemorrhagic exudate.

The postepileptic mental state has been studied by a number of investigators and is especially interesting in the lighter or incomplete attacks. The aphasic state has been spoken of, and we will only add that, when there is a disturbance of speech of appreciable duration, the beginning of recovery is marked by the use, first, of words containing vowel sounds, and then later only of those containing consonants. This fact was first observed by Jackson and formulated in his rule—that simple and quasiautomatic processes suffer least, and are soonest recovered, while complex arrangements suffer most, and are more tardily recovered. The mental state is often expressed by peculiarities in the behavior of the individual, by automatism, and occasionally by violence or the commission of purposeless acts. The patient may be dull, forgetful, or slow in all he does or says. Sometimes, however, the attack acts as an apparent vent, for the epileptic who is dull before the paroxysm is afterward exceptionally bright. In certain cases a blunting of the moral sense, with impulsive promptings, is shown in the performance of various mischievous and dangerous acts.

The *motor disturbance* after a seizure is chiefly transitory. It is most frequently seen as an occasional sequence of hemiepilepsy, the epilepsies following in the wake of infantile cerebral palsy, or organic disease, or injury of the brain in later life. It is to be looked upon largely as an exhaustion of cerebral centers already damaged by gross disease, or, in case the paralysis is more or less permanent, both the epilepsy and the paralysis are but symptomatic expressions of an advancing cortical degeneration. Not infrequently grand mal epilepsy of idiopathic origin manifests itself as an organic epilepsy by a partial convulsion and in such cases transitory palsy is not infrequently seen. Usually the transient paralysis is apparent or most marked after a series of attacks has occurred, this being the case oftenest in hemiepilepsy, in which serial epilepsy is most frequently seen. As successive attacks develop, the weakened parts participate less and less in the convulsive movement of the seizure. The temporary palsy may last but a few hours or may continue for days and weeks, gradually passing off as the exhaustion in general is recovered from. In some cases a vesical weakness succeeds a series of attacks. The extent and duration of these transitory palsies are always in direct ratio to the degree of muscular spasm, and confined and most intense in those parts previously most convulsed.[1a]

Remote Effects of Epilepsy.—The epileptic whose disease is deep seated presents certain conspicuous indications of his disorder. His expression is dull, the eyes lack luster, and the lines of expression in the face are by no means well marked, portraying intellectual and emotional defects. Fibrillary tremors are very common and the lips are puffed and inclined to show a purplish tinge. The skin has an unhealthy look and luster; there is a general evidence of poor circulation and defective nutrition, even though bromides are not used to excess. The tongue often presents old scars, the evidence of former attacks. The patient's movements are not characterized by vigor; they are often slow, awkward, and somewhat incoordinate. Mentally he may present evidences of great weakness, especially if the attacks are severe and frequent. Memory defects are less marked after the petit mal

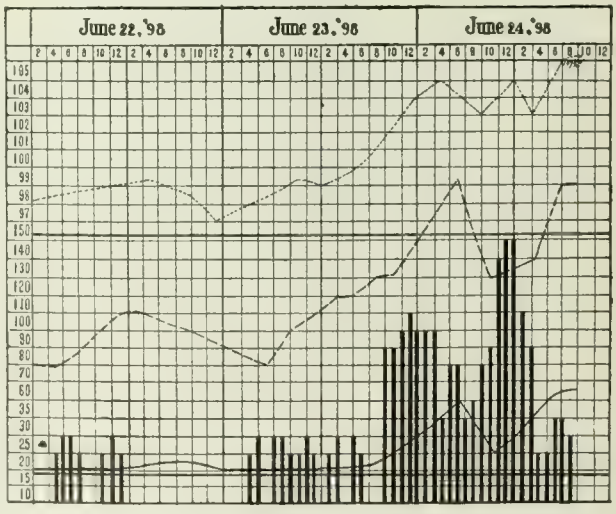

Fig. 2072.—Chart Showing the Clinical Relationship between the Temperature, Pulse, Respiration, and Epileptic Seizures in a Typically Fatal Case of Status Epilepticus. The continuous line represents the respiration, the broken line the pulse, and the dotted line the temperature; the heavy vertical lines indicate the seizures, the number per hour being shown by the figures at the right.

* Courtesy of Dr. Walter G. Chase, who has taken a number of moving pictures of the different stages of epileptic fits at the Craig Colony.

type than that of the grand mal. Some patients show marked mental weakness after relatively slight manifestations of the disease, while others with many severe seizures may preserve nearly their original strength of intellect. There are many epileptics whose paroxysms are purely the expression of an original epileptic constitution, the characters of which are only intensified by the occurrence of epileptic convulsions. This is especially seen in children of inferior physical and mental makeup and from the class of high-grade feeblemindedness. These subjects are, perhaps, able in a weak way to perform acts requiring little intellectual energy, or they grow up presenting characteristics which are overlooked by fond parents. The "strange" child does unlooked-for things, is vicious, or unduly mischievous; applies itself to certain studies, learning with great ease, while it is hopelessly deficient in others. Such a child may display exceptional smartness in mastering some limited "accomplishment."

Whenever the disease becomes firmly established, the interval has a tendency to shorten, and in institutions for epileptics where the severest cases are cared for, most of the patients have attacks daily, or even several in one day. Attacks of petit mal, when interspersed with grand mal, are, of course, much more frequent than the latter.

As before alluded to, there is a tendency in many cases for attacks to occur in groups, although isolated attacks, as Gowers very properly says, are more common, and when the attacks occur in cycles there is little regularity, so far as number is concerned.

Eclampsia and Epilepsy.—Young children are very apt to have one or two convulsions during dentition or at the onset of some of the infectious diseases of childhood which are looked upon simply as eclamptic, and then they remain entirely free from any return until the eighth or tenth year, when several entirely unaccountable seizures make their

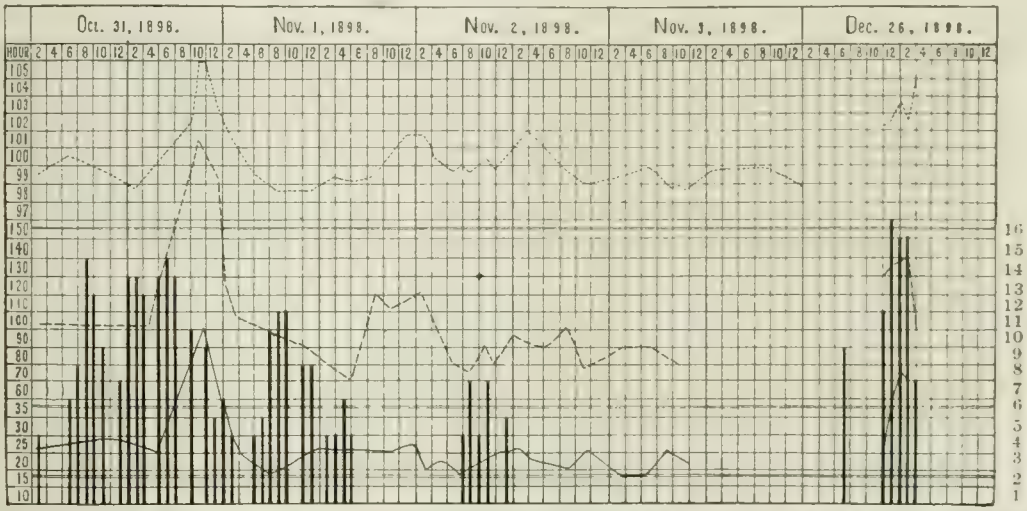

FIG. 2073.—Chart Showing the Clinical Relationship between the Temperature, Pulse, Respiration, and Epileptic Seizures (*a*) in a Typical Recoverable Case of Status Epilepticus, (*b*) in a Fatal Acute Status in the Same Case, Some Seven Weeks Later. The continuous line represents the respiration, the broken line the pulse, and the dotted line the temperature; the heavy vertica lines indicate the seizures, the number per hour being shown by the figures at the right.

Born of drunken or insane parents, at ten it becomes epileptic. Its "queerness" increases, and its fits are not cured; dementia follows, or the type of disease changes, and the infantile attacks are substituted by epileptic insanity; the latter developing, if the subject is a female, in connection with some menstrual derangement or a trying pregnancy or at the menopause.

Time of Occurrence of the Attacks.—Epileptic attacks may be divided into two classes as regards their time of occurrence—*nocturnal* and *diurnal*. The mode of occurrence may be regular or irregular. Recent investigations[2] show that in the tabulation of a large statistical material the attacks are quite evenly divided between day and night. The maximum periods in their order of frequency are in the early part of the night within two hours of falling asleep, in the middle of the day, and in the early morning. The attacks may be very numerous, some patients having as many as several hundred in a single day (status epilepticus). On the other hand, they may be very infrequent, many patients having but three or four attacks a year. I have seen cases in which yearly attacks, or one attack in two or three years, occurred. By far the greater number of patients, however, have attacks every few days or several weeks apart, and women have attacks often just before, at the time, or immediately after the menstrual period.

appearance. The ordinary epileptic history in which the disease appears in childhood is as just stated, but one should be warned that a very small percentage of persons with eclamptic history in childhood ever develop epilepsy in later life. In many cases of epilepsy there is no antecedent history of trouble, but without any cause whatever one or more paroxysms appear, and the possibility of further mishaps of a similar nature keep the patient and his relatives in a state of doubt and uncertainty. The risk of a second attack in a month or so is considerable, and the risk is not much lessened for several months or a year. Too great caution cannot be exercised as regards the giving of an opinion, and while it will not do to say that even the majority of early eclamptic attacks are suggestive of subsequent epilepsy, it is a fact that the early spasms of childhood, occurring perhaps at the third or fourth year, between the periods of the first and second dentition, without great or obvious cause, are quite likely to be the precursors of others, in regard to the character of which there can be no possible doubt.

Status epilepticus is a condition which marks the occurrence of a great number of attacks in a day or several days, and in which one seizure follows so closely in the wake of the preceding attack that consciousness is not regained in the interval. The patient becomes increasingly comatose, the body temperature rises to a great height (105° or 107°), and death soon follows

from exhaustion. Recovery is, however, not impossible. Patients may even recover from the epilepsy itself after a status epilepticus has taken place.[3]

Masked Epilepsy.—There are many forms of irregular seizures which present interesting features. Many of them when carefully observed may be classed under petit mal with automatism accompanying or following the attack. In some instances patients run violently about the room in a semiconscious state before falling into a convulsion. In rare instances the attack may consist almost entirely of a continued running, the patient being unaware of what he is doing. In many cases the patients begin to disrobe or put on extra clothing without knowing what they do. This phase of automatism, or *befogged state*, which follows some cases of the petit mal, may last for hours, days, or even weeks. In cases of the latter duration, however, the state is hardly distinguishable from an epileptic insanity or delirium. During the trance or befogged state the untrained observer may notice nothing unusual with the patient; the latter, however, may take long journeys, going from one city to another, and even transacting business of a simple character without knowing of it afterward. In the majority of such cases the patients busy themselves about senseless, silly, or destructive acts and are frequently picked up by the police as suffering from mild delirium following the abuse of drugs or alcohol. Most patients, while in this twilight or befogged state, are stubborn and resistive and therefore easily run counter to customs of modern life, and altercations with strangers result. Such cases are of great interest from the standpoint of medical jurisprudence. As a rule, the reprehensible acts are motiveless, and are not remembered after commission.

The *interparoxysmal state* may be one free from any nervous trouble whatever, the patient remaining quite well until a new explosion takes place. However, the more carefully such cases are studied the more will be found those who show change in manner which betrays itself in an apprehensive melancholy that may still later give way to a state of great irritability. The pupils during the interparoxysmal period are, as a rule, very mobile and act too readily to light stimulation. The pulse during the interparoxysmal state is usually soft, slow, and compressible. The blood pressure is usually subnormal, only to rise as the next attack approaches. The cutaneous circulation, especially in aged epileptics, is poor; the hands are inclined to be cold and clammy. The nails are dry and brittle. All these constitutional defects are independent of those produced by extreme use of sedatives still too commonly employed in the disease.

The influence of pregnancy has been the subject of much controversy. Epilepsy does not interfere in any serious way with the process of gestation nor induces miscarriage. Pregnancy, on the other hand, almost invariably aggravates the epileptic state itself, and patients are usually left in a worse state at its discontinuance independent of the extra mental stress entailed by motherhood. Suppression of the menstrual flow is apt to precipitate a convulsion, but this mishap is robbed of much causative value in inducing a fit because the majority of epileptic women are very irregular in the periodicity of the menses, a suppression of the same for several months being the rule without any very obvious serious consequences.

The commonly accepted report that certain types of epilepsy may be cured by the induction of malaria or some eruptive fever is entirely without adequate foundation, and should be thoroughly discouraged as a possible hope in treatment. As a general rule, epileptics bear intercurrent adynamic disease poorly, and especially pneumonic disorders.

Etiology.—It is an undeniable fact that heredity plays the most extensive part in the causation of epilepsy. Of 980 cases, no less than 435 presented some family history of neurotic or pulmonary trouble (drunkenness included). Thirty-five per cent. of Gowers' cases were characterized by the same state of things, and with other authors—among them Reynolds and Echeverria—the proportion of cases in which there is a neurotic inheritance varies from thirty-five to forty per cent. As the result of such inheritance, we find that female cases rather preponderate. Of very young subjects this is the rule, but when the disease begins after twenty it appears that there are more males who become epileptic than females. In the greater part of all cases the disease first manifests itself before the twentieth year.

Of 980 collected cases in which the beginning of the disease was known, there were—

	Females.	Males.	Total.
Under 10 years.	103	95	198
Between 10 and 20 years	171	97	268
Between 20 and 30 years	145	92	237
Between 30 and 50 years.....	81	136	217
Over 50 years.....	11	49	60
Total...	511	469	980

Cranial deformities, especially microcephalus, are found with epilepsy, and children whose crania have undergone premature ossification are quite apt to suffer from irregular forms of epilepsy. Ten to fifteen per cent. of children, according to Delasiauve, present epilepsy conjointly with idiocy. The convulsions abe quite apt to be associated with some curious form of intellectual perversion.

The *traumatic causation* of the disease is exceedingly interesting, because of the occasional strange character of the injuries. As a rule, blows which leave only slight or no external signs of their violence are apt, after the lapse of years, to be followed by the outburst of epilepsy. Depressions over the paracentral lobes may be found in connection with unilateral paroxysms. Bullet wounds which perhaps have caused extensive erosion of bone may also be mentioned as causes. In one case, for example, the patient presented a large excavation in the petrous and mastoid portions of the temporal bone, and this wound, which had excited a meningeal inflammation, also gave rise to a very severe epilepsy with maniacal outbursts. Blows producing fracture of the internal table of the skull frequently account for the disease. A scar left from a head injury may be the starting-point of a painful aura which is the precursor of an attack, and various writers allude to injury of the nerve trunks, the sciatic especially, as an important though rare factor. Where desire leads the will captive, which may be the state of mind of the patients and relatives, it is very easy to overrate slight traumata in the etiology of epilepsy. One should therefore carefully weigh such evidence, especially by *x*-ray examination and the most careful neurologic study. Many cases of epilepsy dating from early childhood are due to birth injuries. The majority of such are due to the prolonged labor and its consequent asphyxia rather than to a traumatic injury by forceps delivery. In many cases, however, both factors play a rôle in the etiology and the causation of each cannot be properly apportioned. In recent studies it has been shown that the hereditary factor, family neuropathy, is only a little less frequent in those epilepsies which follow in the wake of infantile cerebral palsy than in the so-called idiopathic disease.[4]

Syphilis plays an important rôle or a cause of true epilepsy. When it rarely does, it usually follows the remote cortical degenerative effects of this disorder, and it is hard to indict this disease as the sole factor. However, attacks of a syphilitic nature are usually preceded by headache and are often associated with other neurotic changes and monoplegias character-

istic of syphilis of the nervous system. The interparoxysmal state is quite apt to be characterized by more or less loss of memory, intellectual weakness, and, in some cases, a great desire to sleep at odd times and places, such a tendency being apparently irresistible. In many cases there is disease of the cranial bones as an intermediate factor. No pains should be spared to determine definitely by serological test the presence or absence of syphilis in any suspected case of epilepsy, even though the neurological examination reveals no clinical symptoms of syphilis.

The *exanthemata* may be followed by the development of epileptic attacks which are often very intractable. This is especially true when scarlet fever has preceded the paroxysms. Not only may this disease have such an influence, but measles, smallpox, diphtheria, and a number of maladies of like nature, may directly cause the epilepsy.

Metallic poisoning is a rare cause, and when we find epileptic convulsions in such cases it is usually symptomatic of some advanced encephalopathy. The use of *absinthe* and *alcohol*, when excessive, is quite apt to give rise to convulsions, which are usually of a violent type. The latter, as a rule, are imperfectly formed, and the loss of consciousness is peculiar. In some the mental derangement is of the nature of a trance, and the patient's seizures resemble the form of the disease known as "masked epilepsy."

In certain cases *great and repeated losses of blood* will give rise to epilepsy. In some cases there is an initial migraine, which exists for some time before the occurrence of the seizures. *Sunstroke* occasionally is the exciting cause of a series of convulsions, which, however, can rarely be called epileptic.

It is not uncommon for an epilepsy to develop at the time the *menstrual function* is established. Herpin reports the case of a girl whose convulsions appeared at the menstrual epoch, and recurred with each succeeding period; Maisonneuve reports similar cases. The suppression of vaginal fluxes is naturally a determining etiological influence.

Sexual excesses are too often supposed to give rise to epilepsy, and masturbation especially is given great prominence as a cause. Onanism is very common among epileptics of low moral gauge, with physical anomalies of development, but it can hardly be considered in the light of a cause. Excessive copulation and lustful excesses are mentioned by Continental writers as playing a part in the creation of the disease.

Of *fear* and *mental worry* and *anxiety* many authors are disposed to speak as important exciting or predisposing causes. There is no doubt of the bad influence of the latter, but the importance of the former is to be admitted with some reluctance, although it cannot be denied that a sudden shock or fright has caused attacks.

Various exciting causes are quite likely to be discovered, especially among young subjects. Many so-called eclamptic, or rather epileptic, seizures are caused by *intestinal worms*, or by the presence of undigested food and the absorption of ptomains. Intestinal worms, while they are often responsible for infantile eclampsia, rarely produce epilepsy in adults. Luykx and Michel report cases in which the disease seemed to be dependent on tenia, and in that reported by Michel the seizures occurred during five years, and ceased with the expulsion of the worm.

Irritation of the *auditory apparatus* is likely to produce epilepsy, and the paroxysms may follow such simple excitation as blowing into the ear. The attacks from such a cause may even be very violent and general.

So far as the influence of *diet* is concerned, we find that continued or excessive indulgence in animal food is likely to predispose to the disease in some persons. Many first attacks may be dated back to an engorgement of the stomach or to some act of gluttony, and in many cases immoderate indulgence in food often constitutes an exciting factor. Portal speaks of several subjects who became epileptics after gluttonous indulgence in beans (Delasiauve), and the older writers also refer to cases in which the ingestion of poisonous fungi or of ergot has been the assigned cause.

Morbid Anatomy and Pathology.—There is nothing that can be called constant or characteristic in the way of a morbid anatomical appearance in the epileptic brain. This disease has existed in connection with almost every variety of pathological change. Meningeal or osseous thickening, exostoses, vascular dilatation and sclerosis, cerebral atrophy and hypertrophy, the presence of tumors—all these lesions have been found to exist in epileptic cases.

Recent histological investigations of the cerebral cortex as to which part of the brain we should primarily look for the epileptic discharges, has yielded some noteworthy results. Bevan-Lewis, Buchholz, and others had previously found changes which seemed to point to atrophy of the nerve cells, and since then Chaslin[5] in particular has made careful examinations of the epileptic brain. He found proliferation of the glial fibers in the cortex, which are arranged, especially in the external layers, into compact bundles of fibrils; there is therefore a kind of sclerosis or gliosis, which may even be apparent to the naked eye. Bleuler[6] has confirmed this change; he found also hypertrophy of the outermost glia layer of the cortex. It is still very doubtful, however, whether these pathological changes are the cause of the epilepsy or the result of the convulsions, as Marinesco and others think. Marinesco thinks that this at least may be regarded as the cause of the glial proliferation, while the other changes, such as atrophy of the tangential fibers and chromatolysis of the cells, may be attributed to congenital disposition and the result of the toxic processes.

Alzheimer[7] has lately demonstrated, by exhaustive investigations, that the changes described by Chaslin occur in cases of epilepsy (and dementia), and has confirmed these changes in a later report.[8] Sailer has also attributed a form of epilepsy associated with dementia to a sclerotic cortical process ("hypertrophic nodular gliosis"). Similar observations have been published by Rosenfeld, Orloff,[9] and others. These forms can be easily distinguished from genuine epilepsy, as Voisin has stated.

Turner[10] lays stress on the defective constitution of the nervous system, in particular on the embryonal development of the Betz cells, etc., and he finds changes in the vascular system which he regards as characteristic. We should refer to the articles by Clark-Prout,[11] Sala,[12] and Buck,[13] all more or less confirmatory of the above contention of a progressive gliosis of the cerebral cortex and basal ganglia.

In fatal cases of status epilepticus, recent changes are found in the blood-vessels, and hemorrhages[14] which are undoubtedly the result of the convulsions and asphyxia. Clark and Prout ascribe the cell changes also to this cause.

Although pathological anatomy has not given us any definite indications as to the site of the disease, other facts point to its nature and site of origin. The view which formerly prevailed and was specially advocated by Kussmaul and Nothnagel, that the medulla oblongata and the pons were the seat of the disease, has been practically abandoned. The experiments of Fritsch and Hitzig, Unverricht, François-Frank and Pitres, etc., have shown that epileptic attacks may be excited from the motor zone of the cortex, and that excision of certain parts of the cortex may arrest the twitching in the corresponding groups of muscles. We know that lesions of the motor area, which are evident to the pathologist, may have the same effect. Although these attacks differ from genuine epilepsy in their unilateral onset, this is due to the fact that the stimulus, whether artificially produced or due to disease, proceeds only from the

motor zone of one hemisphere. If we assume that epilepsy is caused by a lesion of the motor centers on both sides, the difference in the symptoms would be practically explained. The mental disturbances which follow or usher in the attack, and the weakness of intellect which so often develops in the course of the disease, indicate that the cerebral cortex is the seat of the disease. The fact that in diseases which cause complete interruption of conduction in the motor tract of the internal capsule, the paralyzed half of the body may be exempt from the convulsions, is also an indication of its cortical origin. In one interesting case, an epilepsy which had existed for many years disappeared after an attack of apoplexy which had produced hemiplegia. Lately, however, some writers (Binzwanger, etc.) have maintained that subcortical centers, the medulla oblongata in particular, are concerned in the production of the convulsions. Ziehen[15] attributes the clonic convulsions to the cortex, and the tonic to their experiments. Binzwanger expresses the opinion that in genuine epilepsy the original, exciting cause of the convulsion is a primary lesion of the cortex, but that the discharge produced by this excitement takes effect most rapidly and markedly upon the subcortical motor system. He attributes the fall at the onset of the attack to sudden inhibition of the motor functions, but the loss of consciousness is sufficient to explain this symptom. He bases his view on the occurrence of abortive attacks, in which this inhibitory discharge is the only symptom. The epileptic attack is regarded as a discharge of accumulated irritation from the cerebral cortex (Hughlings Jackson).

Some authors are inclined, as already mentioned, to think that encephalitis of the motor area, usually in childhood, may produce the changes which cause epilepsy, but this can apply only to a small proportion of the cases. Redlich[16] has recently advocated this view, pointing out that slight symptoms of irritation and paralysis have often a hemiplegic distribution.

Diagnosis.—The diagnosis of the ordinary epileptic attack is not a difficult matter. The seizure is of such a dramatic and pronounced character that it is scarcely possible to err in regard to its true nature. The minor seizures are sometimes confounded with attacks of syncope, but when we exclude the disorders of motility, which do not belong to the latter, there should be no chance for mistake. It must be remembered that seizures of petit mal do not occur in an isolated form, but that there is a history of numerous previous attacks.

It is important to diagnose whether or not the paroxysm is the manifestation of coarse disease of the brain; and, in such cases, limited or rather extensive paralysis will often be found, as well as optic-nerve atrophy, disturbed reflexes, and distal sensory trouble.

In some instances the diagnosis must be made between the grand attack and the convulsions of *uremia* or *alcoholism*. The uremic convulsion is usually preceded by a history of mental obscuration with perhaps some ataxic aphasia and headache. The presence of edema, albuminous urine, casts, and the skin pallor, furnish confirmatory indications.

The alcoholic convulsions, unless due to chronic alcoholism, are preceded by a debauch. If the urine be examined it will be found that the bichromate of potash test will reveal the presence of alcohol by a very peculiar and striking change of color to green.

Sometimes we may confuse the lighter attacks with auditory vertigo, or with lithemic or gastric vertigo, but the rotary character of the disturbance in the former, and the connection of the latter with digestive disturbance, are to be borne in mind.

It is of the utmost importance that the medical man, especially if he be called upon to treat and inspect soldiers, prisoners, or the inmates of the pauper asylums, should be on his guard in regard to the *simulation of epilepsy*. This form of imposture is common enough, and is very difficult of detection. Various authors upon medical jurisprudence have recorded a number of cases in which a malingerer kept up the deception for a period of several years. The case of "Clegg, the Dummy Chucker," reported by Carlos MacDonald, is of this kind. The subject was an habitual criminal who repeatedly threw himself from high platforms in the jail to the stone floor below, and bore many self-inflicted injuries without a murmur, that he might escape certain duties or punishments. He was finally detected by MacDonald. The impostor cannot change the size of his pupils, nor can he counterfeit the color of the skin which belongs to the real fit. The epileptic, as a rule, doubles his thumb under his other fingers, which are strongly flexed—a thing neglected by the impostor. The latter is ordinarily on the alert to see how his behavior will impress the bystander, and an occasional suggestion from an outsider will be acted upon by the designing person, who will thus betray his consciousness as well as his anxiety to make an impression.

Prognosis.—Epilepsy is certainly one of the most discouraging of all diseases of the nervous system so far as the hope of cure is concerned, but the prognosis is much less bad at the present time than it was before the judicious use of bromides and the attention to diet, occupation, and special therapy to improve the proper nutrition and elimination of waste products from the system. Those forms of epilepsy which are of idiopathic origin, or which are dependent upon coarse cerebral disease, osseous lesions, or advanced syphilis, are well-nigh hopeless, but of those cases which owe their genesis to less profound causes, a few are modified or cured by treatment. It is impossible to give satisfactory statistics of cures, from the fact that most of the cases are imperfectly watched. Sex seems to have little or nothing to do with the patient's chances. The cases in which the disease develops before the tenth year, or after adolescence, are more readily helped than those in which it begins between the tenth and twentieth years (Gowers), and this is probably due to the fact that the idiopathic causation is more common before twenty. The form with grave attacks alone is more easily cured than that in which petit mal is a feature, and uncomplicated petit mal is perhaps the least hopeful of any form. The curability of the disease depends much upon its duration and the number of attacks. Cases of hereditary origin are commonly regarded as less amenable to treatment, but Gowers is not of this opinion. Fifteen per cent. of Gowers' successful cases were those in which heredity existed. In a series of twenty-nine reported cases counted as cured or arrested for a term of years, and published by Clark,[17] twenty either had an heredity of epilepsy or insanity or both in the direct antecedents. Those cases in which the fits are separated by long intervals are most readily cured. Even though the attacks be severe and recur at short intervals, the prognosis is not necessarily hopeless if sufficient general causes in errors of metabolism are in evidence, the removal of which show a rapid betterment in the epileptic state. The presence or absence of an aura does not essentially alter the prognosis, although the existence of an aura may enable one to abolish individual attacks. Cases in which cranial deformities exist are usually bad, though the attacks be irregular and bizarre in character. The existence of marked mental impairment or epileptic insanity is always unfavorable, yet recovered cases of the latter are not very rare. Fatal cases—that is, cases in which the patient's death has been directly due to the disease, either in single attacks or from a serial or status period—are not so very rare. Probably a third of the deaths of all chronic, long-standing cases are to be ascribed to the disease itself. Death in single attacks is usually by asphyxia. Those dying with status do so

from either exhaustion or pneumonia or pulmonary edema. It occasionally happens that epileptics are suffocated from the lodgment of a piece of meat in the air passages, while a number of accidents, among them falls, are apt to lead to death by drowning, by cranial fracture, or by suffocation caused by the unnatural position in which the patient's head has been placed as a result of the fall. In several instances, of which quack advertisements have made great use, the patients fell into an open fire-place, or against a hot stove. We have already alluded to the danger of rupturing a muscle or dislocating a joint.

Treatment.—In our management of epilepsy we are to avoid everything that smacks of routine treatment. No doubt much of its intractableness to therapy is due, first, to the fact that a vigorous and energetic treatment is often not undertaken until the disease is firmly established, and second, that the individual patient is given too little attention and the convulsive phenomena usurp the whole treatment. If epilepsy is to be considered as a disease-entity, the result of variable causes and having different residual anatomical changes in the cerebral cortex and the basal ganglia as its morbid seat, then the disorder is a continuous one of which the attacks are but one of the great and dramatic symptoms. It should be our constant aim to apportion the relative merits of the several causes and endeavor to remove them. An idea of the real nature of epilepsy sketched on as large a disease canvas as the foregoing, gives us a true picture of the ailment we are called upon to treat.

The mere administration of a much recommended drug, even the bromides, without studying the indications for its use, will do no good, but will work great detriment to the patient and his disease. The epileptic paroxysm, after all, is but a discharge from overexcited and unstable nerve cells, and is a symptomatic condition of a great variety of pathological states. As a general plan of treatment it should be our endeavor to maintain a condition of circulatory equilibrium, so that the cerebral blood pressure shall not undergo very rapid, sudden, or great changes. Cardiac stimulants or sedatives should perhaps, form a part of the treatment in different cases, and these may be combined with remedies having specific neurotic or alterative effects. In some cases the use of digitalis is almost a necessity, and in others—those more particularly in which there is a tendency to cerebral hyperemia—remedies of an opposite class are required. In what the older writers called anemic epilepsy, the use of digitalis is absolutely important, or we may use a remedy which was first recommended by Gowers, viz., nitroglycerin, in doses of gr. $\frac{1}{100}$ to $\frac{1}{25}$ thrice daily.

There are a great number of remedies which have been used empirically almost from time immemorial. In many cases no intelligent idea is entertained as to their physiological action. It is not proposed to refer to many of them, except in the most superficial way, for but few possess any virtues.

No general remedies have been of so much service as the bromides, especially those of sodium, ammonium, and potassium, and since their introduction, about fifty years ago, the number of cures has greatly increased. The prognosis has also improved, as our knowledge derived from experimental therapeutics has broadened. In 1865–70, five or ten grains of the bromide of potassium in divided doses was considered a maximum quantity; a few years later certain American physicians advocated immense doses—even an ounce daily. Maximum doses of twenty grains, repeated thrice daily, control the convulsions in cases which are amenable to this kind of treatment—cases in which the attack has perhaps been previously aggravated by very large doses.

In most cases of this grave disease it is of the first importance to ascertain the length of the intervals between the attacks, the time of day at which they usually occur, and the patient's general condition. The amount of bromide to be given daily, say of the sodic salt, which is the best, may be fixed at from one to two drams, to be given in divided doses, the largest one just before the expected attack. Should the latter occur in the early morning, it is best to administer the remedy at night, and perhaps to reinforce the quantity. In some cases in which the periodicity of the paroxysm can be definitely determined the dose may be increased, and the drug used more freely for several days before the expected explosion. Many practitioners commence by inducing a mild brominism, which is manifested by anesthesia of the fauces, and by some appearance of acne upon the forehead, or by the bromic breath. It is exceedingly injudicious to go beyond this point, for when the nutritive processes are interfered with, the medicine does harm instead of good. The bromide salts should always be given in plenty of water, and vichy is a decided improvement over simple water, because of its advantage in securing tolerance of the drug by the stomach. When epilepsy is dependent upon organic changes, either syphilitic or otherwise, a saturated solution of the iodide of potassium or sodium may be used separately and either of these salts given in milk, or vichy should be used in large quantities. The so-called "American System" should be followed in the administration of the iodide, and even half an ounce or more should be given daily. In cases in which the attack is preceded by headache, the iodide is especially serviceable. The bromides may be given in combination with tincture or infusion of digitalis, and small quantities of arsenic may be incorporated for the purpose of preventing skin troubles. In other cases the combination of chloral hydrate or aconite is advisable. The bromic treatment should be continued in a modified form for at least two or three years after the attacks disappear. It will be found, in some cases, that the combination of the three principal bromides sometimes acts more energetically and efficaciously than either singly. The use of fats, especially cod-liver oil, is often of the greatest service when the bromides fail alone. We have been enabled in this way to help many cases in which the bromides had been used before without any considerable success. The administration of the bromides in combination with opium or morphine constitutes the so-called Flechsig treatment. The patient is subjected to a continued treatment with opium or its alkaloid in increasing doses, and afterward when the toxic effects are mildly produced this drug is discontinued, and a course of bromides ordered. Rectal injections of a preparation of the substance known as bromipin have been in use in Germany in doses of ɱxv., the patient being forbidden to use any salt in his food. The nightly enemata of this substance must be increased until three or four grams are taken.

Delasiauve refers to no less than eighty-nine remedies or forms of treatment, and this is but a small number when we consider that his book appeared over half a century ago, and that new remedies are constantly being recommended. The discovery of the bromides, as already stated, constitutes the only real advance in drug therapy. As to the other remedies, it will suffice if we enumerate chloride of potassium, sulphate of zinc, oxide of zinc, sulphate of copper, chloride of gold, nitrate of silver, and phosphorus, as remedies which have had their day but which are still occasionally employed; while the list of vegetable remedies is simply legion. Valerian, camphor, the camphor monobromate, asafetida, musk, castor, opium, belladonna, aconite, indigo, turpentine, and conium are among the most prominent of these.

The question is no longer between bromide and some other drug, but between drugs and drugless treatment. If sedatives have to be used at all they must be chiefly bromide. That this view is the one commonly accepted is shown by the great activity in preparing synthetics containing a large percentage of

bromide. Sodium bromide is not only a palatable and agreeable drug, but it is also cheap and is not inferior to any of the new synthetics.

For years routine sedative treatment has so usurped the field of attention in epilepsy that many physicians have made no serious attempt really to understand the nature of the difficulties confronting them. This has led to great inroads of special faddism in legitimate fields of medicine such as eye-strain and other reflex explanations, and a host of vampire patent remedy venders. Now that we are in the day of real scientific inquiry as to the nature of the individual case, especially the factors of defective bodily functions, there is more hope that we shall know the influence which such disorders have upon the mental and neural make-up of the spasmophilitic constitution.

Bromides should not be used until everything in the physical make-up, in circulation, digestion, and the like important functions, is set quite right, and then the sedatives need to be applied with the greatest caution as they have such potency to injure the functions most desired to remain normal.

A word as to the so-called detoxicating or antiautotoxic regimen. This does not lie in the application of a single resource or a few, but represents the application of most of our modern resources at the same time. Many measures are advocated for no other reason than the possible diminution of the sum of the autotoxic poisons. Sweating and purgation are old but very important resources. During the Bouchard period "intestinal antiseptics" came into vogue and their influence is still in evidence, for now and then an author reports good results from the use of salicylic acid, bismuth, naphthol, and similar drugs, and the supposed antiepileptic power of borax and boric acid is believed by some to be bound up in this form of activity. Much of dietetics and all of the measures securing intestinal drainage and sterilization are based on the idea of detoxication, so that right or wrong the latter conception underlies three-fourths of our modern ideas of treatment. Personally, we believe it is the most rational view to take in applying any general plan of therapeusis in epilepsy.

In the treatment of status epilepticus, likewise, a host of drugs have been recommended, but the following prescription will be found very useful; it can be given by the rectum if the patient is comatose:

℞. Sod. brom. . . . . gr xxx.
Chlor hydrat. . . . . gr. xv.
Morphinæ sulphat. . . . gr. ½
Tr. opii. . . . . gr. v.
Aquæ. . . . . q. s ad. ℥i.

Sig.—One-half ounce, and repeat in two hours if convulsions are not controlled.

In the status the heart should be supported in face of the sedative treatment here advised and the great exhaustion entailed upon this organ as the result of the serial convulsions. This is best done by hypodermic medication of camphor, strychnine, and whiskey.

Diet.—The issue of a proper diet for the epileptic is so very important that I take occasion to submit here a general sample of the same which I have found most useful, and in which the foregoing generalizations are applied.

Breakfast: Cup of cocoa, with cream and sugar. Wheat cereal with cream and little sugar. Two soft boiled eggs, or minced chicken. Rolls, toast, pulled bread, or zweiback. Maximum amount of butter, preferably unsalted. Strained honey, orange marmalade. Plenty of stewed fruit exclusive of those with small seeds, such as berries, etc. No hot bread allowed.

10 *to* 11 *a. m.:* Choice of glass of milk (top), or milk and crackers. Cup custard, junket, egg-shake or raw eggs, chicken sandwich, malted milk, buttermilk, or lactone milk.

Luncheon: No soups. Liquids restricted to less than one glass. No steak, roast beef, pork, salt fish, or shell fish. No sweetbreads or kidneys. No radishes, raw celery, or anchovy. Choice of fresh fish, chicken, lamb, mutton. Fowl of all kinds, except domestic duck or goose. The following can be used freely: peas, beans, spinach, samp, rice, macaroni, spaghetti; any vegetable that may be put through a puree sieve; tender beets and oyster plant, stewed. Boiled potatoes may be taken occasionally, and thoroughly masticated, also asparagus tips, and salad with French dressing. Choice of rice pudding, farina, corn starch, blanc mange, prune souffle, tapioca, baked apple with cream, and prunes. No oranges, grape fruit, or raw apples allowed. Cream cheese, Camembert, and pot cheese may be taken.

4 *p. m.:* Same variety as at 11 A. M. with the additional choice of cocoa with sugar, or a farinaceous dessert such as on luncheon list.

Dinner: Same variety as for luncheon.

While liquids are restricted at meals, water should be taken freely between meals. No alcohol allowed.

Friction, cold baths, and exercise are to be insisted upon, and mild intellectual labor is good for the subject. If possible open fires, properly guarded, should be placed in the patient's room.

Surgical measures have been of avail, if we are to believe all the reports; yet the experience of many successful surgeons, who have watched their cases for a long time, is against their efficacy. If they are to be used it should be only in cases in which the evidence of a traumatic origin is very clear.

In some examples it will be found that the aura proceeds from a cicatrix upon the scalp, and the exsection of this, even if no removal of bone is undertaken, may be sufficient. In such cases as those reported by Lande,[18] in which a neuritis was the cause of the convulsions, exsection or nerve-stretching might do good, but of course such hopeful results are problematical.

Daily Régime.—A general daily régime of baths, diet, and occupation should be specified, adjusted to each case, and the same placed in the hands of the nurse or the patient's relatives, upon which scheme, at least in all severe cases, a written follow-up record should be kept. A sample scheme which we have employed in youthful epileptics is here given:

The patient is placed first of all with a nurse-trainer in a congenial but quiet country environment, away from the family by preference. The daily schedule runs about as follows: The patient rises at 6 A. M. and takes ten or fifteen minutes of a gradually increasing severe grade of active calisthenics with Indian clubs, medicine ball, or weights. He then takes a glass of hot water, a cold shower-bath and a brisk rub-down, and breakfasts on an egg, small amount of cooked cereal, a glass of milk and some stewed fruit. Immediately after breakfast he takes a walk of six to eight miles, which he covers in running and walking in about one and a half hours. He then takes a glass of milk with or without raw eggs, and one or two strips of zweiback. A shower-bath is now given and he lies down for fifteen minutes. He then works at sawing wood or some equally useful occupation until 12.30. The patient next lies down without undressing, sleeps or not for half an hour, and is then given dinner of fish and milk, vegetables, cereals, and stewed fruit. This meal should be eaten in not less than forty minutes. He is then allowed to sleep for one hour, after which he follows some school work or handicraft, and midafternoon lunch follows with rest. From 5 to 6 P. M. he is allowed to follow some light intellectual occupation—reading or study. Supper of milk, eggs, cereal, and stewed fruit is given at 6.30. This meal, as breakfast, is light and should occupy at least thirty minutes in eating. The patient is then allowed games, recreation, etc., until 8.30. He now takes the special treatment of a warm bath and general massage, etc.,

and is in bed for the night at 9.30. No alcohol, tobacco, tea, or coffee is allowed. The patient is encouraged to drink at least two quarts of water daily. High colon irrigations are given every other night, and every ten days castor oil or calomel in divided doses is given. The articles of food in the three-meal diet are changed every fortnight. The occupation is also changed every two weeks if desired. The patient is steadily encouraged to work and play in moderation; complete and absolute rest is also insisted on. A chronological diary report is kept of the day's schedule and is reviewed two or three times a week by the physician. For the first few months, a daily uranalysis is made and charted to cover the solids, urea, indican, and albumin content. Almost without exception, every case showing metabolic defects has either indican or albumin in varying amounts for the first two or three months after coming under the training treatment. In time this disappears entirely if the schedule is carefully maintained. For weeks after the indicanuria is eliminated, some trace of albumin appears in most cases, which seems to be related largely to disturbance in protein digestion. Stool analysis, beyond the grossest examination, has not been of practical service in our experience.

It will be seen from the dietary and daily schedule that the underlying idea of care and treatment is to make the epileptic a robust individual, which should be the main purpose of treatment in every case before any special drug is applied. This preliminary treatment may take several weeks or months. For those epileptics who cannot afford to maintain the training treatment under suitable circumstances there remain the several State institutions established especially for this class. All severe cases, having several attacks daily or weekly, should be referred to these special institutions for care and treatment. In such hospitals or colonies all patients may be treated in accordance with regulations of diet, hydrotherapy, and medicinal agencies. Of individuals suffering from even severe epilepsy who find residence in these institutions, one to six per cent. ultimately recover while a much larger per centage are much improved. In these farm and hospital colonies out-door employment in agriculture and kindred pursuits is provided in abundance. All manner of trades, schools, and occupations are at hand. The several institutions in the different States, organized on the village plan, are located on a large tract of land. Suitable amusements and entertainments are allowed and are carefully selected and adjusted to the individual needs of all the resident patients. The colonization of epileptics has now been under way in this country and abroad for a sufficient number of years to prove that it is a very humane and wise provision for the indigent sufferers from epilepsy; and though the majority of epileptics committed to this form of care and treatment may be doomed to suffer from their disease throughout their lives, their state under such conditions can never be as wretched and hopeless as heretofore.

L. Pierce Clark.

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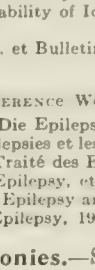
Epileptic Colonies.—See *Colony Treatment.*

Epinephrine,  is the isolated active principle of the medullary portion of the adrenal gland. The chief results of the injection of this substance are marked rise of blood pressure, due to constriction of the arterioles by an action upon their musculature, and increased strength of the heart beat. Dilatation of the pupil, erection of hairs, relaxation of intestinal wall and bladder wall, and flow of saliva may accompany the subcutaneous administration of epinephrine. In general its action corresponds to that produced by general stimulation of the sympathetic nervous system. During life it is assumed that epinephrine is being constantly produced and distributed over the body thus maintaining the muscular tonus. If this distribution is prevented, as for instance, by adrenal extirpation or ligation of the veins, blood pressure falls and muscular prostration rapidly followed by death ensues. In Addison's disease a lack of epinephrine, due to disease of the adrenals is assumed to be responsible for the asthenia which is so noticeable in this condition. When epinephrine is injected in relatively large amounts a transitory glycosuria accompanied by a significant hyperglycemia is in evidence, whereas in disease of the adrenals, as in Addison's disease, the sugar of the blood is reduced to a minimum. See also *Adrenalin.*

Frank P. Underhill.

Epiphora.—See *Lacrymal Apparatus, Affections of.*

Epiphyses.—The exact meaning of the word epiphysis seems more or less a matter of opinion. Various writers define it differently, and sometimes one writer will employ it in different places with different meanings. For the purpose of this article we shall define the word as follows: The epiphysis is that portion of the end of a long bone which develops from a separate center, or from separate centers of ossification. It consists at first of cartilage, later of cartilage and bone, then of bone, which is separated from the main bone by a layer of cartilage—the epiphyseal cartilage. When growth ceases, the epiphysis becomes united to the shaft, and the bone tissue of one becomes continuous with that of the other. The epiphysis then ceases to exist. According to our definition the bones of the adult have no epiphyses, nor does any evidence persist of their original boundaries.

Centers of ossification appear at different periods of time in the several epiphyses, and the epiphyses unite with the shafts at different ages. Until union takes place, growth in the bone continues. When the epiphysis unites with the shaft, growth ceases in that region. Any cutting operation on an epiphysis usually causes its premature ossification and union

with the shaft, and therefore ends the growth of the bone in that place. No cutting or scraping operation should ever be done upon the ends of a child's bones without a full realization of the checking of the growth which will ensue. The greatest bone growth in the body takes place in the lower end of the femur and in the upper end of the tibia. A radical operation upon a child's knee-joint may make a shortening on that side of ten to fifteen centimeters (four to six inches). It is better to take long chances with milder measures, and then, if necessary, to sacrifice the extremity, than to resort to early operation.

Non-operative mechanical injuries may or may not cause premature ossification.

A table of approximate dates of the appearance of the centers of ossification and of the union of the epiphysis to the shaft, follows:

Epiphysis.		Center of Ossification.	Union of epiphysis to shaft.
Head of ribs		18th–20th year.	25th year.
Sternal extremity of clavicle		18th–20th year.	25th year.
Head of humerus		1st year	20th year.
Lower end of humerus		2d year	16th–17th year.
Ulna	Upper epiphysis.	10th year	16th year.
	Lower epiphysis.	4th year	20th year.
Radius	Upper epiphysis.	5th year	14th year.
	Lower epiphysis.	2d year	20th year.
Metacarpals			20th year.
Inner four, digital extremity		3d year	20th year.
Thumb, base		3d year	20th year.
Phalanges of hand, base.	1st row.	3d–4th year	18th–20th year.
	2d row	4th–5th year	18th–20th year.
Femur	upper.	1st year	18th year.
	lower	9th month fetal life.	20th year.
Tibia	upper	At birth	20th year.
	lower	2d year	18th year.
Fibula	upper	4th year	25th year.
	lower	2d year	20th year.
Metatarsals.	outer 4, digital ext.	3d year	18th–20th year.
	great toe, base.	5th year	18th–20th year.
Phalanges of foot, base.	first row	4th year	17th–18th year.
	second row	6th–7th year	17th–18th year.
	third row	6th year	17th–18th year.

Separation of the Epiphysis.—An epiphysis may be separated by violence from the shaft, at any period of its existence. The same result is sometimes brought about by acute disease, but then it is simply an incident in the course of the disease, and does not merit a special description. A reference to the table given above will show the age limit below which the lesion may take place.

Burns (Quoted by Stimson. *Archiv für klinische Chirurgie*, 1878, xxii., 343) found that the epiphyses most frequently separated were those of the lower end of the femur, the lower end of the radius, and the upper end of the humerus. Whitman (*Medical Record*, July 25, 1893; *Annals of Surgery*, June, 1897, and February, 1900) has shown that the upper epiphysis of the femur is separated much more frequently than had been thought.

Displacement of the epiphyses may be partial or complete.

The *cause* of the lesion is usually a cross strain. When the epiphysis moves out of place, it takes with it the periosteum, stripping off the bone. If the displaced epiphysis be not reduced promptly the periosteal new bone may possibly increase the deformity as time goes on, and may render a later reduction harder.

The *symptoms* are largely those of fracture, and in fact there is no reason why the lesion should not be regarded as a fracture. It is practically the same. The crepitus elicited is possibly a trifle softer. In rare instances separation of an epiphysis has been responsible for an arrest of growth in the bone at that spot.

Treatment is practically the same as would be that of a fracture, namely, restoration of the normal relation of the epiphysis to the diaphysis, and retention of it in its proper place. Resort should not be had to open operation, if this can be avoided. If an open operation be done, unnecessary trauma must be avoided.

Acute Epiphysitis.—The bone-marrow in the epiphysis is subject to acute inflammations, and the other joint tissues take part in them. Acute epiphysitis is a modern term for acute infectious joint inflammations in children, but no reason exists for taking it out of the category of arthritis (*q.v.*)

The epiphyseal marrow may be involved in a tuberculous inflammation, but the majority of opinion seems against the possibility that it is the primary seat of the disease. I have never seen a case of separation of the epiphysis in pure tuberculous disease.

Syphilis and other joint inflammations may also locate in the epiphyseal marrow. See the article *Arthritis*.

The epiphyseal cartilage forms a barrier to the spread of disease, a quite efficient barrier until the nutrition of the cartilage has been damaged sufficiently to allow the inflammatory process to perforate it. On this account an inflammation may exist indefinitely in the shaft or in the joint without invading both, but if the periosteum be involved, the invasion may take place at the margin of the cartilage. Cartilage itself is not vulnerable directly to any infection.

Leonard W. Ely.

Epispadias.—See *Penis, Diseases of.*

Epispastics.—See *Counterirritation.*

Epistaxis—The term epistaxis is applied to bleeding from the nasal cavities and adjacent sinuses. Owing to the unusual vascularity of the nasal region, the delicacy of its construction, and its liability to accident nosebleed is of very common occurrence.

Etiology.—It may be due to traumatisms; to local affections of the nasal cavities, such as hyperemia, dilatation of superficial blood-vessels, superficial erosions of the mucous membrane, ulceration; to the presence of foreign bodies or of pharyngeal adenoids; to various systemic affections such as hemophilia, anemia, purpura, and scurvy; to diseased conditions of the brain, heart, liver, or kidneys; to typhoid and typhus fever, measles, scarlatina, diphtheria, pneumonia, etc.; it may be vicarious, occurring in women at the menstrual period; or, finally, it may arise from a variety of other causes dependent upon severe excitation of the circulation or irritation of the surface of the nasal mucous membrane.

It may occur as a result of toxic doses of certain drugs which are eliminated through the mucous surface of the upper air passages. It is present in fractures of the skull, especially at the base, and is also found with necrosis or caries of the bony skeleton of the nose. It has been caused in gunners by the severe concussion of heavy firing. It occasionally follows coitus. Sudden transition from a normal to a rarefied or to a compressed atmosphere may cause it. It is not infrequently the precursor of cerebral apoplexy. It is commonly met with in boys at the age of puberty, and in girls it may precede the establishment of the catamenia. It may occur in women during pregnancy and at the menopause. It is common in childhood, less so in middle life, and again more apt to occur with advancing age.

The bleeding may come from one or both nostrils. Originating from the deeper part of one nasal cavity the blood may be deflected into the nasal cavity of the opposite side, and escape outwardly through that

nostril or into the pharynx. Dangerous nasal hemorrhage may occur during sleep, the blood being swallowed without attracting the attention of the patient. Serious loss of blood may thus result. The presence of bleeding in such a case would probably be demonstrated by changing the position of the patient and causing him to clear his throat.

Bleeding most frequently originates from the anterior and inferior part of the nasal septum, and when it comes from this locality it is seldom dangerous, although in some rare cases it may be severe, and through frequent recurrence it may cause serious anemia.

The bleeding point may be located in any part of the nasal cavity, or there may be a general oozing, widely diffused over the surface of the membrane, as in hemophilia, purpura, and the anemia of children. When coming from the anterior portion of the nares the blood escapes from the nostrils, but when from the deeper parts of the nasal cavities it may pass backward and be swallowed and later vomited, or it may pass into the trachea and be coughed up. The latter accident is not common. When the bleeding is from the upper and anterior part of the nasal cavity the hemorrhage may be serious. This is explained by the close connection between the anterior ethmoidal vessels and the intracranial circulation.

Plethora, especially when accompanied by deficient menstruation, portal congestion, and some forms of Bright's disease, may be relieved by epistaxis.

Hematomata of the nasal cavities are more commonly met with on the septum. They are occasionally seen as the result of traumatism. Examination will often determine the location of the bleeding point, which is apt to be found upon some part of the cartilaginous septum. The anterior region of the nose is the most frequent seat of this trouble.

Diagnosis.—In hemorrhage from the anterior nares the nasal cavity, having been carefully cleansed, should be examined by anterior rhinoscopy, and an attempt made to locate the precise spot from which the bleeding takes place. This will generally be found in the region of the septum. Epistaxis must be differentiated from hemoptysis, from hematemesis, and from bleeding from the lower and median pharynx. This may be done by careful examination of the nasal cavities.

Prognosis.—The prognosis is generally good. When, however, the bleeding is dependent upon a general diathesis or some systemic disease it may be very dangerous.

Treatment.—The treatment of epistaxis must depend upon its origin and upon its cause. It is necessary, therefore, to determine as far as possible what these may be. Vicarious bleedings and those which occur at the crises of certain fevers, may, if they are not excessive, be allowed to continue. In conditions of plethora and in vicarious menstruation it should not be unnecessarily checked. Under ordinary circumstances simple means will usually be effective in stopping the flow. These consist in absolute rest and in keeping the head erect, avoiding the common mistake of inclining it forward and downward. If the bleeding is from the anterior part of the nose, pressure of the ala against the septum may check it. The application of cold to the nose, to the back of the neck or in the wrists, or the insufflation of cold water is often effective. When the bleeding point can be found, applications should, if possible, be made directly to it. This should be done by first drying the place with absorbent cotton and then applying to it nitrate of silver, chromic acid, or even the galvanocautery. Astringents, such as alum or tannin, may also be applied. The iron preparations are as a rule worse than useless, and should never be employed. Of late the use of two remedies has been suggested, both of which experience has proved to be of great value. One of these is antipyrin, the other is the extract of suprarenal glands. The antipyrin should be dissolved in water, about ten grains to the ounce. The suprarenal extract should also be used in strong solution. The bleeding cavity having been freed from clots by means of cold water, about half an ounce of one of the above solutions should be insufflated and retained in the nose as long as possible. This should be repeated once or twice unless the bleeding is immediately checked.

The careful employment of this method is very effective. When simpler means fail, the hemorrhage may be controlled by packing that part of the nasal cavity from which the bleeding comes. For this purpose sponge should never be used. Far better is it to introduce into the nasal cavity a narrow strip of surgical gauze, saturated with antiseptic vaseline, which shall be packed carefully against the required spot. If the bleeding point is in the upper part of the cavity, the lower part may be left free to permit of normal respiration. The proximal end of the gauze strip should be left within reach and in the withdrawal of the tampon only so much should be removed at one time as may be readily detached. Forcible removal is certain to cause a recurrence of the bleeding. Great care should therefore be exercised and the plug should be saturated with some solvent solution before any manipulation is applied to it. As a rule the plug should not be retained for more than one day. If it occurs posteriorly the bleeding may be checked by inserting a tampon into the nasopharynx, and, if

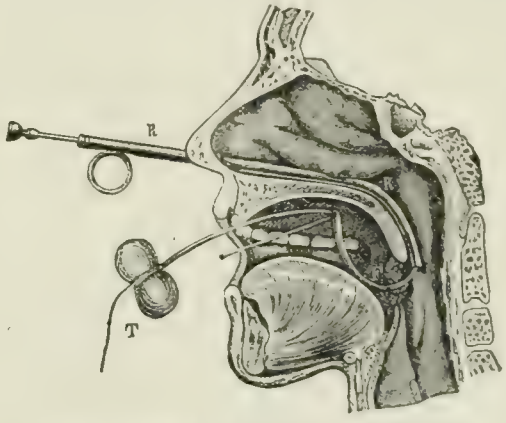


Fig. 2074.—Plugging the Posterior Nares by Means of Bellocq's Sound.

necessary, at the same time packing the anterior part of the nasal canal. For packing the nasopharyngeal region a flexible catheter or a Bellocq's cannula (*R*, in Fig. 2074), to the distal end of which a loop of silk has been fastened, should be passed through the nose and its distal end brought into the pharynx. To the loop a strong ligature should be fastened and drawn upward and then forward until the attached end is outside of the nostril. A tampon of lint or cotton, saturated with vaseline and attached to the middle of the ligature, which should be about eighteen inches long, should be in readiness. The tampon should then be drawn carefully into place by traction upon the string, aided by manipulation with the finger in the pharynx. The tampon having been placed, it is well to make a firm block of absorbent cotton around which the anterior end of the strngi may be wound and held in the vestibule of the nose. The pharyngeal end of the string should be brought out of the mouth and loosely attached to the patient's ear. To remove the tampon, the best plan, as a rule, is first to cleanse the parts as thoroughly as practicable and then apply to them a solution of suprarenal

extract in order to secure the greatest possible contraction of the blood-vessels. Lastly, the parts should be covered with liquid vaseline, and time enough allowed for it to saturate the surface of the tampon as deeply as it can penetrate. Only the gentlest traction should be applied to the string while the tampon is being removed.

Severe bleeding may require the use of revulsives intended to cause reflex contraction of the nasal blood-vessels, the administration of remedies intended to quiet the action of the heart, the application of pressure, externally and internally, and in extreme cases transfusion or some kindred measure. In the most severe and intractable cases of epistaxis the nasal cavity may easily become septic, and thus another serious feature be added to the case.

D. Bryson Delavan.

Epithelioma.—Definition.—The term epithelioma is applied to a group of tumors arising from the epidermis and to growths from the internal organs which show cells of the morphology of those seen in the tumors from the skin. As examples of the first group may be cited the squamous-cell new growths of the lip or tongue so frequently seen in pipe smokers, while as examples of the latter may be mentioned those heterotopic epithelial tumors of the bronchi which, instead of the usual cylindrical cells corresponding in type with those from which they are derived, show cells of flattened form with the special structures characteristic of surface epithelium and with a tendency to cornification. Similar tumors are found along the gastrointestinal tract and in the gall-bladder, kidney, and other internal organs. All of these tumors, including those arising in the epidermis, may be quite correctly considered under the general heading of carcinoma, and in Germany this is the usual custom. The English and French writers, however, are apt to use the term epithelioma as a special designation for tumors arising from the superficial epithelium. Other terms which have been employed, chiefly in clinical writing, are epithelial cancer, cancroid, and rodent ulcer. The general classification which is here followed is based upon that of Darier.

Classification.—Epitheliomata may be divided into (1) those derived from the superficial epithelium; (2) those derived from the deeper or basal-cell layers; and (3) those derived from cells which have been left in the deeper layers of the corium during embryonic life, as in nevi and congenital moles.

1. The tumors derived from the superficial or squamous layer of the skin may again be divided into (*a*) papillary epithelioma or the superficial form and (*b*) squamous-cell epithelioma or the deep form. Both are made up largely of squamous epithelial cells, often showing intercellular bands and spines. The cells as they age show eleidin granules when suitably stained, and tend to form in pearl-like masses.

(*a*) The first variety, the so-called papillary epithelioma, is chiefly seen in old people and is often consecutive to a senile keratosis. The most common sites are the face, lips, neck, and back, or the dorsal aspects of the extremities. The tumor begins as a rough, warty mass projecting from the surface of the skin and attached to it by a broad base. It often remains quiescent for a considerable period, even years, its final stage being initiated by a sudden increase in size. This alteration is frequently accompanied by a history of some injury or irritation of the tumor. The mass often bleeds easily after slight trauma, and may ulcerate and ultimately involve the deeper tissue and the regional nodes, but usually, if removal is early, the amount of actively growing tissue is small and is confined to the base of the growth. Similar papillary epitheliomata are found on the tongue, buccal mucosa, glans penis, and vulva. In tumors from these mucous surfaces the horny layer, which is so prominent in the previous type, is much less evident or may be practically absent. The surface of the growth is white, in cases associated with leucoplakia buccalis; but more often it is red, soft, and shiny. The tumor often remains benign for a long time, but not infrequently it assumes a rapidly destructive course with involvement of the deeper tissues and the neighboring lymph nodes. In both of these forms of growth a diagnosis is sometimes extremely difficult. The

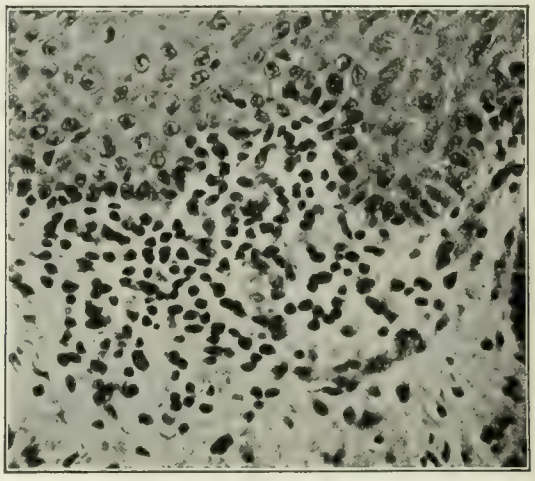


Fig. 2075.—Section from Early Epithelioma of the Lip to show Subepithelial Infiltration in the Corium. × 400.

invasion of the deeper tissue is apt to be over a considerable area and continuous; the cells do not invade the connective tissue in tongue-like projections or in isolated masses, but grow with a solid, disc-like base. Pearls may or may not be present. In either form the finding of mitotic figures is of relatively little value in diagnosis, because these may also appear in the ordinary cutaneous warts which are perfectly benign. An abundant subepithelial infiltration with lymphocytes and plasma cells (Fig. 2075) and certain morphological alterations in the type of the individual epithelial elements themselves may be the only differences between a benign and a malignant growth. The morphological changes in the epithelial cells are chiefly in the increased size of the nucleus, its greater richness in chromatin elements, and a tendency to increase in the size of the cell, as compared to the normal.

(*b*) Tumors of the second subdivision, which includes most of the squamous-cell epitheliomata, begin not as external papillary growths, but as what may be termed inverted papillary forms; that is, the skin is not much elevated, but cells from the deeper layers of the skin penetrate into the subjacent corium. All that may be noted in a beginning tumor is that the affected area is lighter in color than the surrounding skin and that there is a hard, plaque-like mass which can be picked up between the fingers. As the growth continues it ulcerates deeply and the edges overhang the central depression. This type occurs about all the orifices of the body, chiefly on the lips, the tongue, and the floor of the mouth. It is not infrequently the terminal stage of a leucoplakia buccalis. It occurs occasionally in old scars and may follow lupus vulgaris.

Microscopically the tumor is composed of prolongations of the squamous epithelium into the deeper tissues; and, as a rule, unless the growth is an extremely rapid one, there is extensive keratinization of the epithelial cells and the formation of so-called

pearls, which are merely spherical masses of flattened, cornified epithelium (Fig. 2076). The cells in the middle of these "pearls" undergo necrosis, and occasionally, especially in some of the tumors of the scalp, calcification. The connective-tissue stroma is relatively scanty and contains many lymphocytes and plasma cells.

Tumors of this type occur in both the old and the young. The writer has seen an extensive epithelioma of the lip in a boy of fourteen years. They are more

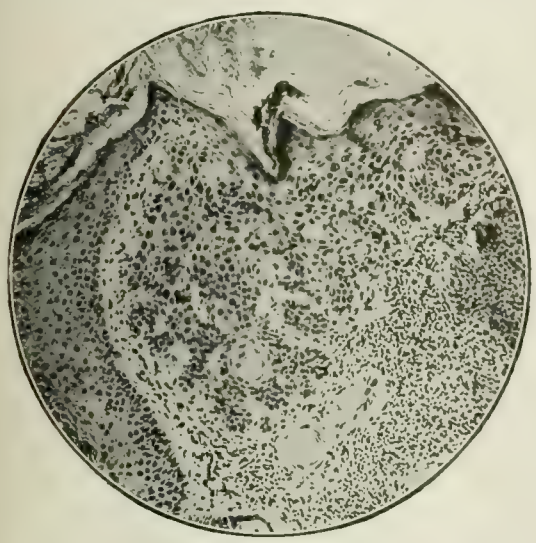


Fig. 2076.—Beginning Squamous Cell Epithelioma of Skin Showing Downgrowth of Tumor Cells and Pearl Formation. × 100.

frequently found, however, in middle-aged and elderly people. Clinically this form of epithelioma is very malignant, the regional lymph nodes being early involved; and if life is prolonged general metastasis may occur.

2. Tumors of the second group, which may be called tubular or basal-cell tumors, differ from those just mentioned both in the type of the cells and in the clinical course. The growths have their origin, in all probability, in the so-called basal layer of the skin or in hair follicle cells, and the cells of the tumor remain relatively small and often retain a spindle shape. They do not, as a rule, undergo cornification and do not show the intercellular bridges and the spines so characteristic of squamous epithelium. In the center of the cell masses there are not infrequently found areas containing mucous, hyaline, or colloid material, giving an appearance which led the older writers to call such tumors cylindromata, endotheliomata, plexiform sarcomata, or even, when the vascular development was excessive, angiosarcomata. The basal cell growths do not project much above the surface of the skin, but extend into the deeper layers. Usually, but not always, serial sections reveal direct contact between the superficial tumor cells and the skin. These tumors have a much slower course than the squamous-cell type, often growing slowly for a period of ten or fifteen years without causing great inconvenience to the host. When extensive and early ulceration takes place, as is not infrequent, the tumors are designated clinically rodent ulcers. They are most frequent in old people, and generally occur on the face, especially on the upper two-thirds, where eighty per cent. of the epitheliomata are of this type. They are seen more rarely on the lips, tongue, scalp, neck, pharynx, chest, and genital organs. As a rule, there is less inflammatory reaction around a non-ulcerated growth of this type than about the squamous-cell epithelioma. A moderate amount of ulceration, however, is usual, and following irritation by scratching there is not infrequently formed over the tumor a crust, which then separates leaving a depressed shallow cavity over which a new crust forms. Such a tumor very rarely involves the regional lymph nodes and almost never forms metastases at a distance. Owing to the benign nature of the tumor it frequently shows a distinct tendency to heal spontaneously, and in its early stages it is easily cured by freezing with liquid air or carbon dioxide snow, by curettage, or by the application of large quantities of radium.

3. The third form of epithelioma is that arising in moles, which may or may not be pigmented. Usually such a mole remains quiescent for a period of years, and then, often following irritation or sometimes without any apparent reason, begins to grow rapidly. Ulceration is apt to occur early, and the tumors may show a tendency to form secondary nodules in the skin at some distance from the original growth. If the original tumor is pigmented, the secondaries may show pigment or may not. The coloring matter in many of these tumors seems to be carried by certain specialized cells, called chromatophores, the exact nature of which has not yet been determined. Many writers still consider them as of connective-tissue origin. Extensive invasion of the regional lymph nodes is common in this type. The cells are spherical or fusiform and are often inclosed in well-marked alveoli. Microscopically these tumors are sometimes considered as sarcomata on account of the morphology of the cells, and unquestionably many of the so-called melanosarcomata arising in the skin belong more properly to the epithelial group. A differential diagnosis is often difficult and sometimes impossible, and can best be made by taking into consideration the history of the case, and by the use of certain special stains for connective tissue which show that the fine fibrils usually lying between the individual cells of a sarcoma are absent in the epithelial tumor.

Fig. 2077.—Sebaceous Adenoma of the Skin. × 250.

A fourth group of tumors having certain genetic relationships with both the second and the third varieties described may be included under the general title of epitheliomata. Their exact nature, however, is as yet somewhat obscure, and as they are of exceedingly rare occurrence sufficient material has not been accumulated to permit of a definite determination of their origin, nature, and clinical course. Because they are, as a rule, benign these tumors have usually been classed as adenomata, one group

being the sebaceous adenomata arising presumably from the sebaceous glands (Fig. 2077); another the hydradenomata supposed to arise from the sweat glands; and a third the benign cystic epitheliomata which are in all probability simply a subdivision of the basal cell form already described.

In addition to the name benign cystic adenoma, these tumors have been called epithelioma adenoides cysticum, by Brooke; lymphangioendothelioma, by Juliusberg; trichoepithelioma papulosum, by Järisch; acanthoma adenoides cysticum, by Unna; carcinoma adenogenes of the skin, by Ribbert; and finally and most recently, adenoide nevoepithelioma, by Hoffmann.

From the confusion in nomenclature alone it is evident that the statement that the exact nature of these tumors is still in doubt is justifiable. There are certainly three clinical varieties, of which two can hardly be considered as true tumors. These are the sebaceous adenomata, which are merely hyperplasias of the sebaceous glands of the external skin or the mucous membranes, and the hydradenomata which also are growths limited in extent, not involving the surrounding tissues, and properly considered at the present time as merely adenomatous hyperplasias of the sweat glands.

The growths usually called benign cystic adenomata are, on the other hand, unquestionably of true tumor nature. Those writers who have recently made a thorough study of the subject describe the tumors as most frequently multiple, occurring chiefly on the scalp, but occasionally over the entire body, either minute or reaching ultimately the size of a fist, with a reddish or yellowish surface, and lobulated or smooth.

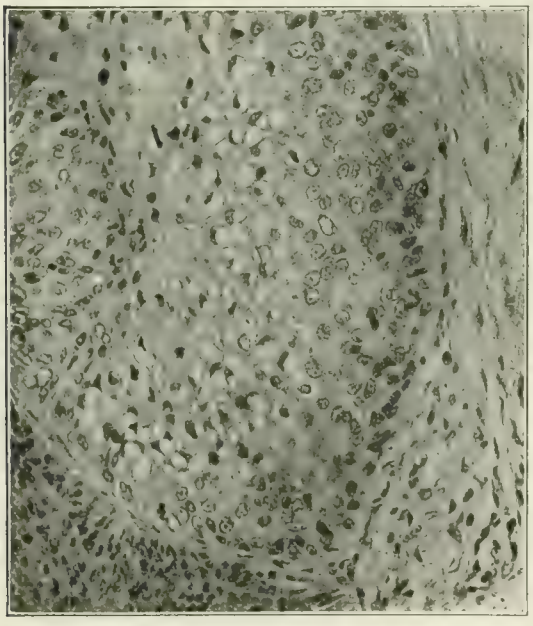


Fig. 2078.—Recurrent Adamantinoma of the Jaw. × 200.

The subjects of these tumors may remain in good health for years, despite the presence of a large number of growths scattered over the body. Ulceration may occur, and in a few cases metastases, resulting in death, have been reported. As a rule, however, the growths remain localized and do not even extend throughout the skin lymphatics, much less involve the regional lymph nodes. The patients, as a rule, die of some intercurrent disease. Almost all of the described cases have been in old people, although two of the patients were under thirty years of age. See *Epithelioma, Multiple Benign Cystic, of the Skin.*

Microscopically the tumors are found to be made up of small spindle or oval cells arranged in tubule-like masses, the center of the gland containing either colloid or hyaline material or débris. This débris may become calcified or may act as an irritating substance causing the formation of foreign-body giant cells. As a rule, the masses remain quite discrete and do not infiltrate the neighboring connective tissue. In some of the cases, serial sections have demonstrated the connection of the alveolar tubules with the cells of neighboring glands, the hair follicles, or the basal layer of the epidermis. These tumors undoubtedly originate in some cases from congenital defects in the formation of the skin. In other cases they may take their origin directly from normal elements under the influence of some determining factor such as irritation or senile alteration.

Though differing somewhat from the other members of this group, there may be mentioned here an infrequent tumor appearing in the upper or lower jaw and derived from epithelial remnants of the enamel organ of the teeth (Fig. 2078). These adamantinomata, as they are called, are usually benign, but may recur after operation. In structure they are made up of a richly cellular connective tissue inclosing alveoli filled with epithelial cells. At the periphery of the alveolus the cells are cylindrical, while the center is filled with cells of a stellate form. No intercellular bridges are present between the individual cells, nor does calcification occur.

Etiology.—Some of the etiological relationships of the epitheliomata in general are better understood than those of other tumors. Their histological peculiarities have also been studied with the greatest care by Ribbert and others, since owing to their superficial position they are easily obtained at an early stage. Almost all observers agree that irritation is an important agent in inciting malignant growths of this type; and this probably accounts for the fact that such tumors occur most frequently on the face, since this portion of the body is exposed to traumatic action, to atmospheric agents, and to sunlight, and more often shows the senile degenerations of the skin and the leucoplakial alterations which not infrequently precede an epithelioma. The multiple occurrence of superficial epitheliomata also points to some common agent, probably irritation either physical or chemical. As concrete examples of tumors following irritation may be mentioned the well-known epitheliomata of the lip and of the tongue in smokers, the epitheliomata which arise from the base of an ulcer produced by the fragment of a tooth, and those beginning in the scars following lupus vulgaris, all of which show that a large part is played by irritation. Many of the basal cell groups, on the other hand, unquestionably arise from small masses of cells left during the embryonic development of the skin, and the same congenital displacement is, no doubt, responsible for the formation of the moles and nevi; but while irritation certainly plays a part, just what determines the final change from a resting indifferent cell in such remnants to one endowed with powers of rapid growth, is as yet unknown. Unknown also is the answer to the important question: Are the changes in the connective tissue primary, thus releasing the epithelium from tissue restraint; or are such changes the expression of an altered metabolism in cells already endowed with the qualities of malignancy? In connection with the "benign cystic epitheliomata" a distinct hereditary factor has been noted.

Note.—The general subject of epithelioma is treated in Ribbert: Das Karzinom des Menschen, 1911. The monograph of Krompecher: Der Bazalzellenkrebs, 1903, illustrates many interesting tumors of this type. The classification of the tumors is described in condensed form by Darier: Précis de dermatologie, 1909; and the subject of the benign

cystic epitheliomata has been reviewed by Frieboes: Beitrag zur Klinik und Histopathologie der gutartigen Hautepitheliome, 1912. For a study of adamantinomata and related tumors, see Malassez: Les débris épithéliaux paradentaires, 1910.

FRANCIS CARTER WOOD.

Epithelioma of the Skin, Multiple Benign Cystic.—*Synonyms:* Epithelioma adenoides cysticum (Brooke); Acanthoma adenoides cysticum (Unna).

The first extended monograph on this subject has recently appeared (1912), the author being Walter Frieboes.[1] Going back to 1826 he has collected notes of twenty-two cases, one being personal. This series which forms a separate expression of disease does not include many cases which have been reckoned—under one name or another—as belonging under benign epithelioma. He makes a number of clinical forms, depending on the site, and also on the size. The scalp and external ears seem to be favorite sites. Unlike previous classical authors Frieboes includes large, lobulated, and broken down, ulcerated growths along with the small pinhead to pea-sized, formations. His plates are as different as possible from those of text-books, as they show the scalp, ears, and face of a woman covered with large, smooth, or lobulated growths, several of which are badly ulcerated. These larger growths have been known as multiple endotheliomata of the skin, but histologically they are with a few possible exceptions benign epitheliomata.

It is also evident that many cases clinically termed benign epithelioma, have really quite a different histological structure, so that numerous types may be thus differentiated. Hoffmann would make of all of these a single group disease *adenoid acanthepithelioma*. The present description of the disease conceived as consisting only of small lesions may be allowed to stand. The large lesions of Frieboes are at least extremely rare and the above mention may suffice until more is known of them.

FIG. 2079.—Multiple Benign Cystic Epithelioma showing Down Growth of Surface Epithelium. Spencer, one inch; ocular, one inch and one-quarter. (Original.)

SYMPTOMATOLOGY.—The affection is characterized by the presence of numerous pale-yellow, pearly, or pinkish-colored nodules, from the size of a pin's head to that of a pea. The small growths are quite firmly embedded in or project above the skin. Some of the tumors are translucent and closely resemble vesicles, while others are made up of milium-like bodies and are traversed by minute capillaries. The face, scalp, neck, upper part of the back, and chest are the sites of predilection. In general the growths are discrete, but they tend to group themselves about the root and alæ of the nose, the eyebrows, and the mouth. The confluence of several nodules has been noted.

In the majority of cases heretofore reported the affection has been observed at or before the age of puberty.

The small, pinhead-sized growths increase slowly in size until they attain the size of a split pea, seldom larger, and in very exceptional cases they only undergo ulceration or disappear spontaneously.

They impair in no way the general health nor do they give rise to subjective sensations of any kind. The entire course of the disease, except in the case

reported by White[2] is so free from any evidence of malignancy that the word *benign* has been employed to qualify the term *epithelioma* used to designate this singular eruption. White's patient, in addition to numerous small nodules of the usual type, presented three or four open epitheliomatous ulcers involving the entire thickness of the skin.

Single, hemispherical, brownish-red, or translucent nodules have been removed from the ala of the nose, the eyelids, or other parts of the face and have been found to have a structure identical with or closely allied to that of the multiple benign tumors in question. They may develop in early adult life or in older individuals, but they pursue a relatively benign course.

The cause of the affection is obscure. In Brooke's[3] and my own cases[4] a distinct hereditary history was obtained. The onset of the affection at the age of puberty may depend in some manner on the general stimulus to which all epithelial tissues are subjected at this time. The view has been held by some that these tumors depend on misplaced embryonic epithelial cells which remain latent until puberty or later in life.

Pathology and Morbid Anatomy.—In the earlier descriptions of the affection the cases described by Jacquet and Darier[5] as "Hydradénomes eruptifs," by Török[6] as syringo-cystadenoma, and by other writers with designations of similar meaning, were considered to be of the same general nature.

Unna[7] has, however, wisely separated the class of cases described by Jacquet and Darier, Török, and others from those of Balzer, Brooke, and myself; the first group of cases being, in his opinion, adenomata of the coil ducts, to which he gives the name "syringadenomata," while the second group undoubtedly originate in the epidermis and are called by him "acanthoma adenoides cysticum."

The microscope shows these benign epithelial growths to be made up of proliferating masses and narrow tracts of small epithelial cells corresponding to those in the lowermost layer of the epidermis and external root sheath of the hair follicles. The origin of the new growth from the epidermis and hair follicles is shown in Fig. 2079, which represents a section from the original case described by me.[4] Similar observations have been made by Brooke[8] and by Bowen (in White's case).

The epithelial masses and tracts on their outer side are usually surrounded or defined by a well-marked layer of cylindrical cells, a condition which characterizes many benign epithelial growths. Atypical "pearl bodies," enclosing horny or colloid tissue as well as colloid degeneration of individual epithelial cells, have also been met with. The connective tissue between the new cell growths is somewhat condensed and the seat of a moderate infiltration of lymphoid cells.

Treatment.—Some of the small tumors can be removed by incising the overlying epidermis and expressing them by moderate pressure. If this method is not successful the dermal curette may be employed, followed by the application of acid nitrate of mercury. This leaves a small depressed scar. The method of choice, however, in the removal of these small tumors, especially when situated about the eyelid, is electrolysis. A very insignificant scar results from this mode of treatment.

John A. Fordyce.

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2. White: Jour. Cutaneous and Gen.-Urin. Dis., p. 477, 1894.
3. Brooke: British Journal of Dermatology, p. 271, 1892.
4. Fordyce: Journ. Cutaneous and Gen.-Urin. Dis., p. 459, 1892.
5. Jacquet et Darier: Ann. de Dermat. et de Syph., p. 317, 1887.
6. Török: Monatsheft f. prakt. Dermat., p. 116, Bd. viii.
7. Unna: Histopathology of Diseases of the Skin, p. 117.
8. Brooke: Brit. Jour. of Dermat., p. 269, 1892.

Epithelium.—The *epithelial tissues* consist of cells of various forms, held together by a small amount of intercellular substance. The intercellular substance may be of the nature of a cement or of a fibrillar character. Epithelial tissues are usually non-vascular and are derived from all three layers of the triploblast, ectoderm, mesoderm, and entoderm. They line cavities and cover surfaces that are normally in relation with the air, and secrete, excrete, absorb, protect or receive impressions of sense (special senses). Lymph spaces may exist between the cells and nerve fibers terminate upon them. The cells are usually soft and vary considerably in size and shape; this variation in shape of the same cells is well shown in hollow organs as the urinary bladder where the form of the cell depends upon the degree of the distention.

The varieties of epithelial cells are as follows:

Common:
1. Squamous, (*a*) simple, (*b*) stratified.
2. Columnar, (*a*) simple (*b*) stratified.

Modified:
3. Ciliated, (*a*) simple, (*b*) stratified.
4. Goblet.
5. Pigmented.
6. Transitional.

Specialized:
7. Glandular.
8. Neuroepithelial.

1. Squamous cells occur either in a single layer as simple, or in many layers as stratified. *Simple squamous cells* (Fig. 2080, *a*) are thin, flat, plate-like elements. Upon surface view they are polygonal and give the appearance of a pavement. The cells are usually clear and may show fibrils extending from one cell to another. These cells occur in capsule of Bowman and descending limb of the uriniferous tubule, in the alveoli of the lungs, and the ventricles of the brain.

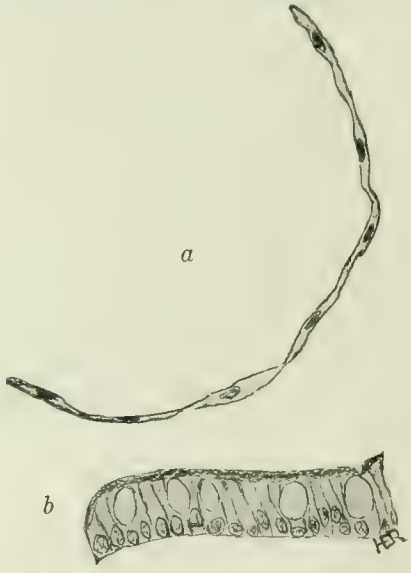

Fig. 2080.—*a*, Simple Squamous Cells of the Capsule of Bowman of the Human Kidney. *b*, Simple columnar and goblet cells from a villus of the human small intestine.

The *stratified squamous cells* (Fig. 2080) consist of many layers of the cells, the upper ones of which alone are squamous. The basal layer is columnar, succeeding layers polyhedral; the upper cells of the polyhedral layer become gradually flattened and pass into the superficial layer of scales. These scales also overlap one another. In the epidermis the upper cells of the polyhedral layer contain a peculiar granular substance, *eleidin*, and this region is called the

stratum granulosum; between the layer and the scale is a clear band, the *stratum lucidum*, in which the eleidin has formed a homogeneous substance, *keratohyalin*. The scales form a thick layer here and are hard and horny due to the *keratin* present. Pigment granules are present in these lower layers throughout the skin of the colored races and in certain regions of the body in white races.

Fibrillation of the cells is exhibited in all layers as shown by L. Merk (1900), Weidenrich (1901), and Nussbaum (1909). The superficial cells are supplied by reproduction of the deeper layers. The cells so formed are pushed upward and replace the cells that are lost on the surface. The cells of the deeper layers of all stratified epithelium are separated from one another by spaces that are bridged by processes from

Fig. 2081.—Skin of the Palm of a Child at Birth, showing stratified squamous epithelium.

one cell to another. These spaces may vary in extent at different times and such cells are called *prickle cells* (Fig. 2082).

Stratified squamous cells are found in the epidermis, lining the mouth, pharynx, esophagus, anus, vagina, and covering the tongue, vocal cords, and epiglottis.

2. Columnar cells also occur as simple and stratified. *Simple columnar cells* (Fig. 2080, *b*) are prismatic in form, but the shape and size vary greatly. When viewed from the side, they are not regular, but fit into one another. Viewed from the top, they are polyhedral in outline. According to Schaeppi (1907) intercellular bridges are said to exist. The protoplasm varies in structure in the various regions. In the intestines, the protoplasm of the free border of the cells is different in structure and striated, forming the *striated*, or *cuticular border*. This striated border may be removed from the cell by fixing agents and usually adheres to its neighbors, coming off as a membrane of varying size. The protoplasm proper may be fibrillar or granular and contain fat and other products. The nucleus may produce a bulging of the cells at that point or it may be basally located. Simple columnar epithelium is found in the stomach and intestinal tract, penile portion of the male urethra, gall-bladder, and many gland-ducts.

Stratified columnar epithelium (Fig. 2083, *a*) is that variety in which the superficial layer is of the columnar type. The basic or genetic cells are col-

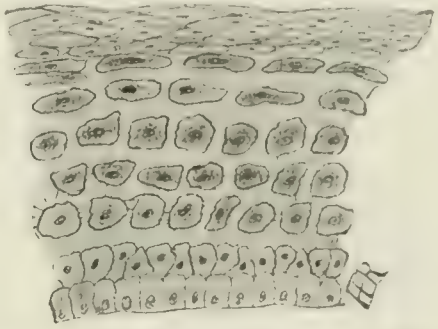

Fig. 2082.—Stratified Squamous Cells showing Prickle-cells.

umnar, the succeeding layer or layers polygonal, and the exposed layer, column-shaped. These cells are found in the vas deferens, membranous urethra, and some ducts of glands.

3. Ciliated cells may occur in the simple or stratified forms. *Simple ciliated cells* consist of a single layer of columnar or cuboidal elements, the exposed surface of each possessing short hairs, or *cilia*. The cilia extend into the protoplasm of the cell and each is connected to a small, darkly staining body, the *basal particle*, that may be a derivative of the centrosome. In some animals the cilia continue toward the base of

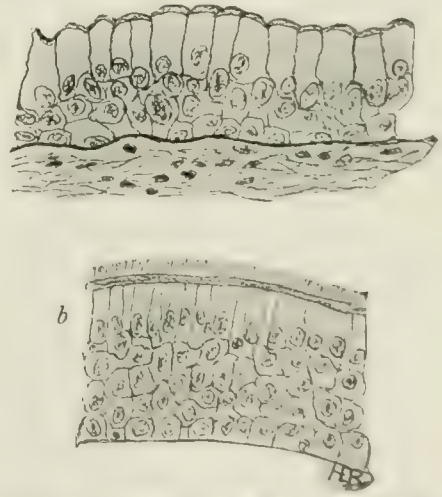

Fig. 2083.—*a*, Stratified Columnar Cells of Vas Deferens of Guinea-pig, showing a cuticular border. *b*, Stratified ciliated cells of child at birth showing a cuticular border.

the cell, approaching a common area or point. This variety is found in the uterus, oviducts, smaller bronchial tubes, central canal of the spinal cord, and brain ventricles. The constancy of the cilia in the uterus is questioned by Keller (1909) and S. H. Gage (1904). The writer after examining many sections of human uteri, has found ciliated cells in only a small proportion of cases.

The *stratified ciliated epithelium* (Fig. 2083, *b*) consists of a genetic layer of columnar cells, one or

more layers of polygonal elements, and a superficial layer of columnar cells bearing cilia. The variety is found in the nose, accessory nasal fossæ, pharynx, larynx, trachea, bronchi and larger bronchial tubes, and the epididymis. In the epididymis the hair-like processes are not considered true cilia as they are not vibratile, extend into the cytoplasm only a short

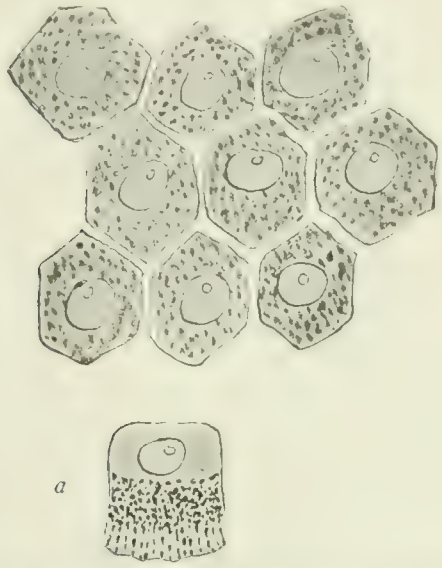

Fig. 2084. Pigmented Cells of Human Retina (surface view). *a*, Cell showing pigmented processes. (After Greef.)

distance, and do not possess basal particles (Myers-Ward, Gurwitsch, H. Fuchs). Goblet cells are interspersed among the ciliated elements.

Ciliary movement was discovered in the mussel by Heide in 1683, although Ham and Leuwenhoek had noticed the movements of the spermatozoa earlier. The movement is usually rapid, in a definite direction and of a rhythmic character; in higher animals it consists of a bending of the cilia and a return to the vertical position. The function of the cilia in man is to move liquids (usually mucus) over a surface toward the exterior of the body. Ciliary action is

Fig. 2085.—Transitional Cells of an Empty Bladder. (After R. W. Harvey.)

influenced by external conditions as are ameboid movements.

4. Goblet cells (Fig. 2080, *b*) are in reality unicellular glands. These cells are found in simple and stratified columnar and simple and stratified ciliated epithelium. When distended with mucus, each cell is goblet-shaped, the nucleus and fixed cytoplasm are pushed to the base of the cell, while the mucin occupies the remainder. When the secretion is discharged, the cell is of an irregular columnar type. The secretion makes its appearance in the form of granules, *mucinogen*, which increase in number and size and respond to special stains. When secretion occurs, the granules absorb water, swell, and run together to form a single droplet of *mucin*.

Each goblet cell possesses a diplosome that lies near the middle of the peripheral half of the cell. It is in this region that the mucin is formed.

5. Pigmented epithelial cells (Fig. 2084) are those in which pigment is found. The pigment may be either diffuse or granular in character. In the epidermis of the colored races and certain regions of the body of the white races, pigment granules exist. According to Kromeyer and Rosenstadt, the pigment is formed within the cells.

In the pigment layer of the retina the cells are not columnar in type, but irregular. The pigment granules are numerous and their position in the cells varies according to the light. If the cells are fixed during exposure to light, the granules lie chiefly between the nucleus and free surface; if fixation

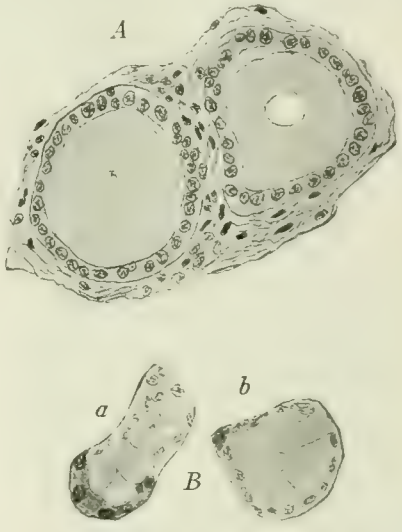

Fig. 2086.—*A*, Tubules of a Human Thyroid Gland; *B*, tubules of a human submaxillary gland; *a*, tubule showing a demilune; *b*, cross-section of a tubule.

occurs in exclusion of light, then the granules lie about the nucleus. This pigment absorbs the extra light waves and also effects a chemical change in the visual purple of the rod cells that are bleached by light rays and reconverted to visual purple by the pigment cells.

6. Transitional cells (Fig. 2085) represent a peculiar intermediate form of protective epithelium between stratified squamous and stratified columnar cells. The genetic layer consists of columnar elements and these are succeeded by two or three layers of polygonal or pyriform elements.

The surface cells vary as follows: in the bladder and ureters, when empty, these cells are polygonal or cuboidal, while in the distended bladder they are flattened. In the urethra they remain polyhedral. This variability of shape indicates the elasticity and extensibility of epithelium as pointed out by Harvey, 1909.

7. Glandular epithelium (Fig. 2086, *A*, *B*) is that specialized form concerned with secretion and excretion. The form of glandular cells varies, according to the gland, from spheroidal to polyhedral, cuboidal, columnar and pyramidal. The protoplasm is usually granular, these granules indicating the formation

of a secretion. Immediately after secretion, the protoplasm is usually clear. As the glands vary in structure, this form of cells is best considered with each individual gland.

8. Neuroepithelial cells are those of epithelial origin performing a special sense function. They occur as the rods and cones of the retina, hair cells of the internal ear, gustatory cells of the taste buds, olfactory cells of the olfactory mucosa, and tactile cells of the epidermis. These are discussed under the various organs in which they occur and under *Nerves, Histology of*.

Serous and Mucous Membranes.—The subject of epithelial tissues would be incomplete without a consideration of serous and mucous membranes and glands.

Mucous membranes line passages that normally communicate with the air, may secrete or excrete, are lined by epithelial cells of any variety and contain all four divisions of tissues. They are found lining the alimentary and respiratory tracts, all communicating cavities and glands; the genitourinary tract.

A typical mucous membrane consists of four layers:

a. epithelium,
b. basement membrane,
c. tunica propria,
d. muscularis mucosæ.

The *epithelium* may be of any variety and may secrete, excrete, absorb, or protect. The *basement membrane* is a delicate membrane upon which the epithelium rests. It is not demonstrable in all mucous membranes. It seems structureless, but special preparations show that it consists, in part at least, of flattened elements that may be united edge to edge or by delicate processes forming a flattened basket-work (Flint). The *tunica propria* consists of a delicate meshwork of areolar connective tissue supporting blood capillaries, lymphatics, and nerves, and in various places lymphoid tissue and glands. The *muscularis mucosæ* consists of two layers, inner circular and outer longitudinal, of involuntary, nonstriated muscle tissue. The muscle fibers are arranged in bundles that form the two layers.

Mucous membranes may be regular in surface outline, or form *villi*, *papillæ*, *rugous folds*, or *glands*.

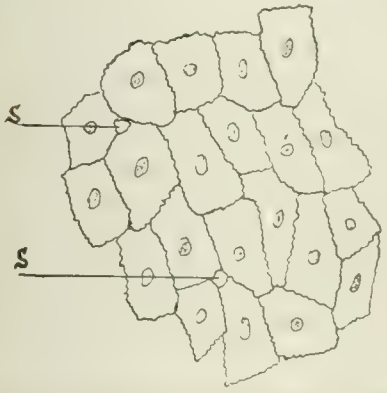

Fig. 2087.—Endothelial Cells, Surface View. *s.s.* Stomata.

Serous membranes are found lining cavities that do not normally communicate with the air (the female peritoneal cavity excepted). A serous membrane consists of a single layer of *endothelial cells* and represents only connective and nerve tissues; it is found in the peritoneal, pleural, and pericardial cavities; lining the blood vascular and lymph vascular systems, joint cavities, bursæ and tendon sheaths, tunica vaginalis testis, subdural and subarachnoidean lymph spaces of the nerve system. They are smooth, moist, glistening, and transparent and are constantly lubricated by lymph.

A serous membrane consists of a single layer of *endothelial cells* resting upon fibroelastic *subendothelial tissue*.

The endothelial cells, or *mesothelium* of Minot (Fig. 2087), are flattened plate-like elements of variable size forming a pavement. The edge may be serrated and intercellular bridges may be present (M. Heidenhain and Kollossow). Brunn states that the free surface of the endothelium is covered with a thin layer of vertically striated protoplasm. These cells as Gronroos pointed out are of connective tissue origin. The subendothelial tissue consists of a layer of delicate fibroelastic tissue supporting blood capillaries and nerves. Lymph spaces are numerous. *Stomata* or small openings between the cells have been described; these are usually bounded by radially placed endothelial cells and lead into lymph channels beneath the surface. These stomata can readily be demonstrated experimentally.

Glands.—Glands are offshoots or derivatives of mucous membranes or epithelial surfaces. *Goblet cells* are considered *unicellular glands* while all of the other glands are *multicellular*. The epithelial elements are arranged in definite groups and these *secretory units* perform a physiological function.

Glands are classified as to (1) *structure*, (2) *secretion*, (3) *outlet*.

1. *Structure.*—In the different glands the secretory units differ in form hence the following varieties of glands are given:

Tubular: (*a*) simple, (*b*) coiled, (*c*) branched, (*d*) compound.

Tubulo-alveolar.

Alveolar or Racemose: (*a*) simple, (*b*) compound.

Tubular.—Simple tubular glands, (Fig. 2088, *A*) as found in the cardiac portion of the stomach, the small and large intestines, are mere tube-like evaginations of the mucous membrane. Each gland is lined by simple columnar (glandular) epithelium and varying numbers of goblet cells. In the lower end of the small intestine and in the large intestine goblet cells predominate. The cells rest upon a delicate basement membrane and this is supported by the tunica propria.

Coiled tubular glands (Fig. 2088, *B*), the sweat and ceruminous glands, are simple tubular structures the lower portion of which is coiled upon itself. Each gland consists of the deeper, coiled, or *secretory part* and a straight tube that connects this with the surface, the *duct*. The cells of the secretory portion are simple columnar or cubodial cells; these rest upon a basement membrane which is supported by the intertubular fibrous tissue. This coiled mass is surrounded by a capsule of white fibrous tissue. The duct is practically straight and is lined by simple cuboidal cells that cease at the epidermis.

Branched tubular glands (Fig. 2088, *C*), as found in the pyloric portion of the stomach, in the duodenum, uterus, and prostate, consist of a number of simple tubules that open into a common duct. Here the simple tubules are the secretory units and their structure is analogous to that of the simple tubular glands. The duct is lined by simple columnar cells.

Compound tubular glands (Fig. 2088, *D*), are quite complex in structure. Each consists of a single main tube or *duct* that divides and redivides many times; the terminal divisions lead into the *secretory units* that are tubular in character and of varying length. The cells lining the secretory portion are of the simple columnar or cuboidal type; the smaller ducts are lined by simple columnar cells while the main duct is usually lined by stratified columnar cells. The entire gland is usually large and is surrounded by a capsule of white fibrous tissue. Examples of compound tubular glands are the liver, the kidneys, thyroid, testicles, and lacrymal glands.

Alveolo-tubular glands (Fig. 2089, *A*), are those in which the secretory units are in part tubules and in part saccules, as represented by the submaxillary, sublingual, and mammary glands.

Alveolar or saccular glands (Fig. 2089, *B*), are those in which the secretory units are all of the saccular type. The simple glands are mere sac-like evaginations of the mucous or epithelial surface; in the sebaceous glands these saccules are completely filled by polygonal epithelial cells.

Compound racemose glands (Fig. 2089, *C*), are those in which the main duct divides and redivides and end in terminal, *secretory saccules;* in the sebaceous glands these saccules are filled by polygonal epithelial cells; in the pancreas and the parotid gland the saccules consist of a single layer of pyramidal (glandular) cells that rest upon a delicate basement membrane that is supported by the interstitial fibrous tissue. The whole gland is surrounded by a capsule of white fibrous tissue that sends in septa that divide the organ into lobes and lobules. In all the glands the interstitial and interlobular tissue serves for the support of the blood-vessels, nerves, and lymph channels.

2. *Secretion.*—The function of a gland is to give rise to some substance that is to be used by the body or to remove substances that are waste products. In the case of the testicle and ovary the secretion is a cell while the other glands form liquids. The secretion of the salivary glands may be *serous, mucous,* or *mixed;* these terms are applied to the respective glands.

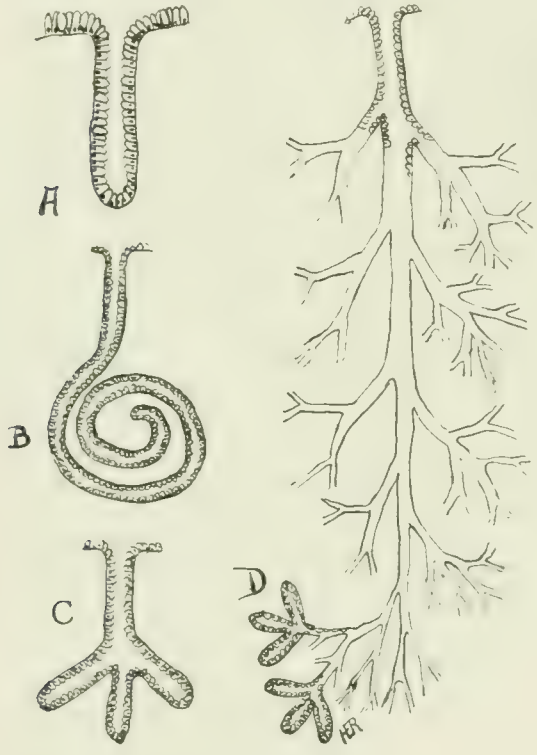

FIG. 2088.—Diagrams of Tubular Glands. *A*, Simple tubular, *B*, coiled tubular; *C*, branched tubular; *D*, compound tubular.

Serous glands, pancreas, parotid, and some small unnamed glands, secrete a thin, albuminous liquid; the cells stain deeply and are usually smaller than the cells of the mucous type. These glands are compound racemose, as R. Metzner pointed out in 1909.

Mucous glands, as the small glands of the tongue, esophagus, trachea, and, according to some, the sublingual gland, are of the compound tubular type; the secreting cells are large and stain lightly.

Mixed glands are those that give rise to both serous and mucous secretions at the same time, due to the presence of both varieties of units. They show the characters of both of the preceding forms and are represented by the submaxillary and sublingual glands.

The functionating cells of some glands contain delicate intracellular or *secretory capillaries* (Stöhr, J. Arnold, Noll) which are considered by some to be transitory structures.

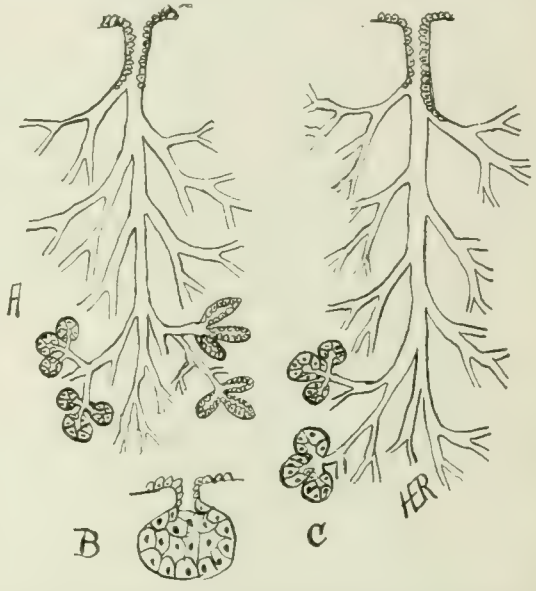

FIG. 2089.—Diagram of Alveolar Glands. *A*, Tubulo-alveolar *B*, simple alveolar; C, compound alveolar.

During the formation of a secretion various changes take place in the cells; these are of a complex nature and cannot be considered here in detail. They are not the same in all glands. H. Hoven has pointed out that the mitochondria of cells play some important part in the formation of secretory granules. With regard to the nucleus, Walker and Tozer have shown that it takes an important part in the formation of secretion products.

The excretory glands are very important as through them the various waste products, formed by the activities of the cells, are eliminated. These glands are the kidneys, sweat glands, and the lungs.

3. *Outlet.*—Most glands are or were connected to an epithelial surface; those which are so connected are called *externally secreting* glands while those that have no ducts or outlets are the *ductless,* or *internally secreting* glands. Such glands are the thyroid, parathyroids, adrenals, hypophysis, ovary, coccygeal, and carotid bodies. In the ovary and testicle and pancreas are groups of epithelial cells that form secretions that are not emptied into ducts; these secretions are received, probably, by the blood-vessels of those glands and then carried to those parts of the body requiring them. H. E. RADASCH.

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Equilibrium.—This term is used in medicine in a literal sense (bodily equilibrium) and in several figurative senses; it is to the former that this article

relates. The word means equal balance and in physical terms suggests (Stedman) "a state of repose between two or more antagonistic forces which exactly counteract each other." One has only to observe for a few moments a baby learning to walk or a girl learning to skate to realize that the process of maintaining one's physical equilibrium (equilibration) is a very complex affair and not easier certainly on the average than the maintenance of one's "mental equilibrium"; both cases imply adequate neuromuscular control.

Three groups of receptors especially are concerned in equilibration: the kinesthetic, the visual, and the labyrinthine.

Kinesthesia furnishes the data as to position and tonus, on which alone the central nervous system can coordinate the skeletal muscles and so, most always subconsciously, maintain the *status quo*. If one who has no acrobatic skill tries, for example, to stand twenty seconds on his hands instead of his feet he realizes, by the contrast, how subconscious has become the almost equally complex process of equilibration in the latter, far more common, posture. The central nervous system (the spinal and cerebral "greys") have to possess a working knowledge of space before equilibration is conceivable at all. The space-mechanism in man may be something along the lines of the following analysis:

The origin of the idea of space in the mind of the individual, like "space" itself, has as yet not been studied out in any detail, so that we have none too good an idea of what is neurally concerned in this matter. For a part of the origin of this idea we certainly have to go back in our imagination to early infancy, as indeed we have already suggested. The eyes alone probably do not give the infant a sense of depth when it is born, a fact hard, indeed, for the adult to realize, because space, time, and causality form the three basal categories of the whole adult understanding, from an empirical viewpoint. As is well recognized, there are two opposed theories in regard to the development of the idea of space in the individual. The first of these, known as the nativistic theory, supposes that the space idea is born in the child, and the second, the genetic theory, believes that the idea is developed only when (voluntary?) movements begin, and that the retinæ of the infant at first give him a knowledge of space in only two dimensions; on this supposition, all objects appear only as particolored areas, without depth.

We must stop to recall a little how such a bidimensional notion gradually develops into a true idea of depth. The first factor of this spatial process, basal for the neurology of voluntary movement, is the kinesthetic sensations of vision. The six extrinsic muscles of each eyeball all work at once by actively relaxing or by contracting. These muscles have the most sensitive of all kinesthetic sensations, more sensitive than any other in the body unless it be in the skin, the proportion of nerve supply to an eye muscle being four or five times that of the gluteus maximus, for example; thus their kinesthetic control is very sensitive. We do not have clear vision, of course, unless the lines of sight of both eyes come exactly upon the foveæ centrales; as a result, in almost every movement of life, at almost every moment, movements of the extrinsic muscles of the eyes themselves, together with the movements of the head and of the neck, must contrive to keep the line of sight of each eye exactly upon the fovea of each retina. If one were standing still and a moving object was perceived partly back of him he would turn his eyeballs in order to see; failing by this means, he might turn his head around, and he might even have to turn his whole body in order to see more clearly. These movements of the head and of the neck, or even of the whole body besides, together with the movements of the extrinsic eye muscles, are purely reflex adjusting movements adapted [illegible] to clear vision. The stronger the stimulation in the biological scale of values the more necessary [illegible] to turn the head around and the farther down the body are the muscles innervated in the process of adjustment. All this, of course, is familiar physiology, but without a doubt the kinesthetic impressions arising in all such adjusting movements as these connected with vision are a prominent factor in the development of our idea of space during the first two years of life.

In addition to the gross movement of the eyes there are the well-known fine adjusting movements. The spokes of the wheel of an automobile going at the rate of about twelve miles an hour furnish a fine opportunity for observation of these inconspicuous adjustments of the eyes, for in the frequent momentary apparent stopping of the wheels we can see when the minute jerks of the eyeball occur. These are wholly unconscious under ordinary conditions, but they serve importantly to finish out the gross adaptive movements of the eyes. They, doubtless, are a factor in the spatial kinesthesia, although wholly unconscious to the adult.

In an homologous way we might consider the kinesthetic sensations from the ears, similar to but less important than the kinesthetic sensations of vision. We turn our ears toward a sound, and thus hearing also helps somewhat to give us an idea of space. The movements of the human pinna are ordinarily so slight that we disregard them, and in any process of adjustment we use the muscles of the neck and the trunk chiefly in order to turn our organism "toward the sound."

This kinesthesia complex obviously is a factor, however small, in our idea of space in which to move.

Another element of this space evolution is possibly represented in the retinæ themselves. It is difficult, if not impossible, however, to understand how these visual impressions alone could give us a sense of depth. Location by means of the retina itself (a form of local sign) is very inexact and, upon the whole, retinal sensations are of little account considered as separate from the kinesthetic sensations of vision (which they never are) in the theory of voluntary movement. It seems that we use the retinal sensations proper in the guidance of a motion only when the line of sight comes upon the fovea centralis, and then it is the usual kinesthetic sensations that guide the voluntary movement. In moving the hand we certainly use the eyes chiefly to determine where we shall begin and where stop the movement. The eye locates the start of an average voluntary movement in the light, but the retinal sensations are too inexact for fine adjustments of the eyes or of the limbs. None the less, we mention them as a probable factor in space conception.

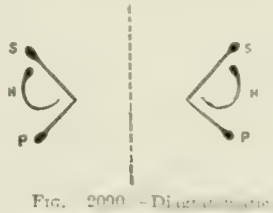

FIG. 2000.—Diagram of the Horizontal Section through the Head to Illustrate the Planes Occupied by the Semicircular Canals. *S*, Superior; *H*, horizontal; *P*, posterior. (After Waller.)

The semicircular canals also have a part in this process of elaboration of our space conception, a very important part, probably, in particular in its relation to the innervations of voluntary movements. Here more anatomically and definitely than elsewhere are the three dimensions of space represented. In connection with the cerebellum (the great center of mechanical coordination of all afferent influences, at least) we have probably to consider the canals, therefore, as the space receptors proper, with meaning, however, only in reference to and in neural coordination with general muscular activity.

A fourth factor in the spatial mechanism of our

minds is comprised in the kinesthetic sensations combined from bodily movements always in space. Such movements as kicking and impulsive reaching out for objects and many other reflex movements send into the young infant's brain a great multitude of kinesthetic impressions, and these effects from movements made in the three directions gradually combine themselves with those from the movements of the eyes and from the canals to furnish a real idea of depth. Thus gradually the concept of space or of perspective is developed, but it must be noted that it is developed wholly from actual muscular movement, whether it be the eyes, the canals, or the joints (usually all together) that are concerned. The movements of the adult, made in the three planes and represented by different sets of sensations, are carried out continuously on this notion of depth, and the adult neuromuscular mechanism appears to work always upon this basis only.

Now equilibration is, neurologically speaking, the intrinsic or inherent phase of this "knowledge" of extrinsic space, so that we have above practically already described the neural apparatus of equilibrium —maintenance so far as kinesthesia (and this basal sense is now properly considered inclusive of touch) is concerned, and by implication the visual factor.

For the labyrinthine element in equilibration we may well quote the brief account of Cleghorn:

We see from the above that the sense of equilibrium is served by various special senses. However, we have good reason for believing that there is one special sense organ which determines the position and direction of the movements of the head, and consequently of the whole body. This organ consists of the system of semicircular canals in the internal ear (anterior, posterior, and external).

Various experiments performed on birds show that a motor disturbance invariably follows division of any

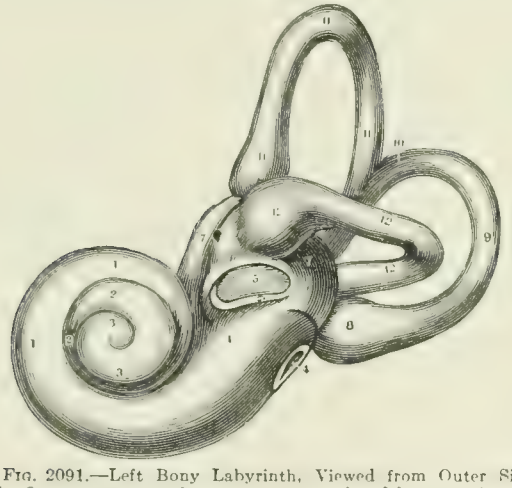

Fig. 2091.—Left Bony Labyrinth, Viewed from Outer Side. The figure represents the appearance produced by removing the petrous bone down to the denser layer immediately surrounding the labyrinth. 1, 2, 3, The first and second turns of the cochlea, and the cupola; 4, fenestra rotunda; 5, foot-plate of the stapes; 7, the vestibule; 8, 11, 12, the ampullæ of the semicircular canals; 9, 11, 12, semicircular canals.

of these canals. The animal shortly after operation, whenever it is disturbed, undergoes peculiar forced movements with rolling of the eyes. When at rest the animal does not maintain its perfect erect position, its legs spreading farther apart than normal and its body coming closer to the ground. The effect of this operation varies, of course, very considerably, it depending altogether on the number of the canals cut. Some observers have claimed that it is the activity of the hair cells on the *cristæ acusticæ* of the ampullæ of the semicircular canals, which are irritated by the increased or diminished pressure of the endolymph in them, which gives rise to a nervous impulse and so originates various ideas of position.

The anatomical position and relationships of these canals in the human being have been very extensively studied by Crum Brown, who pointed out that the three canals of each side lay in the three dimensions of space and that the canals of each side are almost at right angles to one another (see Fig 2091). Any

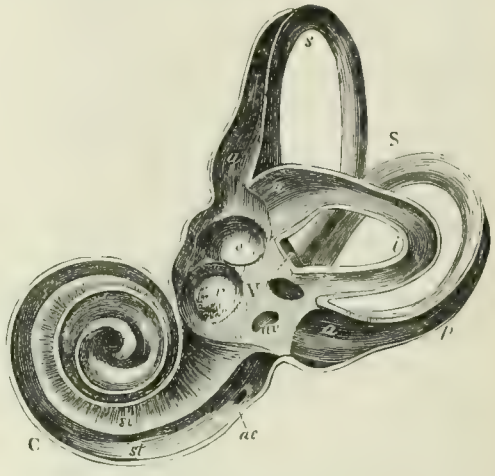

Fig. 2092.—Interior View of Left Bony Labyrinth After Removal of the Superior and External Walls. *n*, *p*, *i*, The superior, posterior, and horizontal semicircular canals; *a*, *a*, *a*, ampullæ; *av*, opening of the aqueduct of the vestibule; *V*, vestibule; *ac*, opening of the aqueduct of the cochlea; *sv*, scala vestibuli; *st*, scala tympani; *o*, fenestra ovalis; *r*, fenestra rotunda.

movement of the head will constantly produce an increase of pressure in the ampulla of a canal of one side, with a corresponding decrease of pressure in the same canal on the opposite side and this by exciting the hair cells in them originates the sense of movement. This assumption can be considerably strengthened by experiments on man. A person with the eyes bandaged, tactile and muscular sense eliminated, supported on a rotating table, can determine very correctly in what direction and through how great an angle he may be rotated. It will be found in the same experiment that after being rotated for a few moments and then the table brought to a standstill, the person will experience the sensation of rotation in the opposite direction. Patients with some disease of the internal ear are very seldom subject to dizziness caused by rapid rotation or the motion of a swing. James has pointed this out in deaf-mutes who are subject to this and to another well-known peculiarity. Should a deaf-mute dive into deep water when bathing, the pressure of the water surrounding the body is nearly equal and so eliminates localized pressure; the mute may then, instead of swimming to the surface of the water, continue his progress toward the bottom—in short, he cannot distinguish whether he is going up or down. In support of this fact it may be mentioned that in birds and fishes whose environment is such that muscular and tactile sense can contribute little to the sense of equilibrium, the semicircular canals are very greatly developed. We find also that in cases of disease of the semicircular canals in which the pressure in them is considerably altered we have well-marked symptoms of vertigo and incoordination. Disease of the cochlea does not produce this. According to Lee, section of these canals in fish produces no forced movement, but section of the nerves supplying the ampullæ invariably gives rise to forced movements. This observer also found that when a fish is placed in different positions, there is an opposite

movement of the dorsal fin and of the optic axes determined by the semicircular canal in whose plane the movement is made. Lee places great importance upon the presence of otoliths in the vestibular sacs of the nerve terminals and the *cristæ acusticæ*. These bodies form large masses in the ears of fishes and they undoubtedly exert considerable pressure on the hair cells.

The semicircular canals are not entirely necessary for the preservation of equilibrium, yet the muscular, tactile, visual, and other senses supplying their quota of information regarding the position of the body may, no doubt, to a considerable extent, take the place of the semicircular canals when these are destroyed by either operation or disease.

The first suggestion of the importance of the semicircular canals in maintaining the body equilibrium may be traced to the two important researches by Purkinje in 1820, and another by Flourens in 1828. Against the usually accepted theory that the semicircular canals are the organs for determining the spatial relations of the head, Cyon contends that the semicircular canals only assist indirectly in this function. He maintains that really our knowledge of the position of the bodies in space depends more upon the nerve impulses coming from the contracted ocular muscles, pointing out that the oculomotor centers are in close relationship with the centers receiving the stimuli from the semicircular canals. Consequently on excitation of the semicircular canals oscillatory spasms of the ocular muscles occur at the rate of from twenty to one hundred and fifty per minute. And this view of Cyon's that the semicircular canals influence the movement of the eyes has been partially supported by Lee (see above). Ewald has divided the labyrinth functionally into two parts, one concerned with hearing and the other with muscle tone. The former is the cochlea, and the latter the semicircular canals of the vestibule. He states that if the labyrinth of an animal be injured and then the animal killed, rigor mortis does not in most cases occur. Sewall carried out a series of experiments on young sharks and skates and claimed that cutting through the canal on one side produced no alteration in equilibrium. But should the utricle be injured and the otoliths be removed the fishes usually dived and swam toward the injured side. Ewald claims that the saccule is more concerned in the equilibrium than any other portion of the internal ear.

Anatomical evidence clearly points to the fact that the function of the semicircular canals and that of the cochlea are different. It is true that the eighth nerve supplies them both; but it is also true that the eighth nerve really consists of two divisions, a vestibular and a cochlear portion, which, although running together in the human subject (in the horse they are separate and distinct nerves), on entering the internal auditory meatus they separate and are distributed as named.

From the foregoing description we can see that the sense of equilibrium is one of the most complex phenomena in the body. As already mentioned, it is made up from impressions derived from nearly all the special senses. Experimental evidence clearly points to the fact that the semicircular canals are of primary importance, that they transmit their impulses to the cerebellum through the vestibular nerve, and the cerebellum in turn, acting through the vermis, may react upon the cerebellospinal and vestibulospinal efferent system and so through these contribute a factor to the normal tonus of the spinal, cranial, and motor cells.

In conlcusion it may be mentioned that although we have seen that the semicircular canals and vestibule are primarily concerned in equilibrium, yet pathological cases have been found in which a slowly progressive affection of the internal ear ultimately left these structures transformed into a bony mass in which no trace of the original soft structures remained. And in these cases there was no perceptible disturbance of equilibrium, nystagmus, or [illegible]. We must therefore admit that these organs are not indispensable for equilibrium, but that some other organ or combination of organs can vicariously carry on their function.

The question may also be asked, Are the semicircular canals concerned in hearing? Certainly injury to these canals in animals does not appear to cause deafness, but it must be remembered that it is extremely difficult to substantiate any of the special senses in animals. In the human subject it is doubtful if any of these structures are ever affected without causing deafness; but it must here be noted that these structures are seldom affected in the human being without the cochlea becoming involved in the disease, so that deafness may be caused by disease of the semicircular canals, which disease would, in all probability, also involve the cochlea.

The cerebellum has long been supposed to be the great switchboard concerned in the association of visual and kinesthetic impressions, and nothing has been discovered to displace this function as long as we consider that probably no individual muscles are represented in the cerebellum, (but rather in the spinal grey) the cerebellum receiving, then, tendencies to movement of muscles already physiologically grouped. As Cleghorn says:

"The cerebellum has long been regarded as the nervous center for equilibrium and coordination of muscles. Certainly pathological evidence points to the fact that the cerebellum is concerned in this function, giddiness being a well-marked symptom of cerebellar disease, although it is not so well marked as in labyrinthine or eighth-nerve lesions.

"Should a large portion of the cerebellum be destroyed, we have well-marked incoordination phenomena, and here, although sensation may remain good, the incoordination must be ascribed to a loss of impulses which regulate body movements without being on their way or in the cerebellum elaborated to conscious sensations.

"Experimental work on the cerebellum seems to point to the fact that the organ 'functions' as a whole, not in 'areas' as the cerebrum, because it is so largely concerned in the innervation of the muscular system of the whole body, and this fact led Flourens and Bouillard, early observers, to express the opinion that the cerebellum was the organ of 'equilibrium.' The cerebellum, according to Lussana and Carpenter, receives impressions originating in the sense organs of muscles, joints, ligaments, and tendons, and it also is intimately connected with the vestibular nerve, consequently destruction of one side of the cerebellum greatly lowers the muscular tone of that side. Removal of one-half of the cerebellum gives well-marked symptoms of incoordination and partial loss of equilibrium. Complete removal of the organ does not give such marked symptoms, but profound lassitude is marked, following execution of movements which should be ordinarily quite unfatiguing. In unilateral ablation the animal usually lies on the side from which the portion of the cerebellum is being removed and with the trunk often curved concavely to the same side. The four limbs are usually extended, the one on the operated side more than the other. There is conjugate deviation of the eyeballs to the opposite side. As a rule, the animal cannot stand and has a great tendency to fall to the injured side. Should it try to move, it will move around in the long axis of its body toward the injured side. In a few days, the majority of these symptoms disappear. However, entire disappearance of the symptoms has not been obtained.

"Although an enormous mass of work has been done on the cerebellum, very little definite knowledge has been obtained. It appears that this organ is concerned in a particular class of phenomena, rather than in a particular sense. It is more intimately

concerned in receiving impulses from the various senses, more especially of those concerned with equilibrium and muscular sense. Through it habitual posture is supported and it is immediately associated with the movements depending principally on the lower cerebral sense, that is, walking and running, and not with those elaborated with the highest technical movement."

The work of Luciani, Adambirenicz, and others on the cerebellum, which led them to emphasize the afferent function of the cerebellum, seems in no way to controvert, but rather try to modernize the former doctrine.

We have "touched only on some of the high places" in thus hurrying over an outline of equilibrium, for it includes in its physiology much of the relationship between the body as an object moving, both passively and actively, in space and that space itself as part of the environment teeming with stimuli. When this broad way of looking at the matter is employed it is here obvious, as it elsewhere is, that kinesthesia is the dominant sense so far as bodily use and orientation are concerned, although only an aspect or perhaps a phase of the integrated total personal control in which all the other senses each in its way, are implicated, and separated only for scientific description and discussion. Of such empirical integrations, equilibrium is a typical example.

GEORGE V. N. DEARBORN.

Equinox Spring.—Bennington County, Vermont.

POST-OFFICE.—Manchester.

ACCESS.—Via Bennington and Rutland Railroad, a link in the Central Vermont line between Montreal and New York.

Manchester-in-the-Mountains, a charming village in the southwestern part of Vermont, is situated on a plateau about 200 feet above the Battenkill River, and 1,000 feet above tidewater, in a valley between the Green and Taconic ranges. For nearly half a century it has been one of the principal resorts of New England, famed alike for its beautiful scenery, fine drives, healthful, invigorating air, pure water, and numerous brooks, alive with trout. The place has been properly termed a model village, the main street being bordered by wide lawns, overarched by century-old elms and maples. Shaded by these trees are marble side-walks, and back of them the cottages in their setting of emerald, the entire absence of fences on the street giving the effect of a park. The village contains a beautiful library building, charming drives in all directions, good hotels, and other desirable features too numerous to mention here. In the immediate vicinity is an unending variety of natural attractions. Away off on Mount Equinox, 1,500 feet above the village and 2,500 feet above the level of the sea and far from any habitation, is located the spring which supplies the Equinox mineral water. An analysis of this water by Messrs. Chandler and Pellew, of New York, shows the following ingredients:

ONE UNITED STATES GALLON CONTAINS:

Solids.	Grains.
Sodium bicarbonate	0.5512
Sodium chloride	0.4783
Potassium sulphate	0.0772
Calcium sulphate	0.1484
Calcium bicarbonate	1.9787
Magnesium bicarbonate	0.7338
Iron oxide and alumina	0.0139
Silica	0.1796
Organic and volatile matter	Traces
Total solids	4.1611
Total residue on evaporating at 240° F.	2.8888

A slightly alkaline water of great purity.

The Equinox is a large spring, flowing from one and a half to two barrels per minute. The temperature of the water remains at 38° F. both winter and summer, proving that the source is deep. The spring is little affected by rains or drought. The water flows from a seam in the talcose schist rock, and is piped direct to the bottling works.

This water is very lightly mineralized, as shown by the analysis, yet it is recommended as useful in the treatment of gout, rheumatism, dyspepsia, and disease conditions generally which are traceable to the so-called uric-acid diathesis. EMMA E. WALKER.

Erasistratus.—He flourished about 300 years before the Christian era, and is esteemed to have been the greatest Greek anatomist since the time of Herophilus, who preceded him by only a few years. According to the historian Strabo, Erasistratus was born at Julis, in the island of Ceos, in the Aegean Sea. He practised medicine for a certain number of years, and then, after he had retired, and was somewhat advanced in years, he began the study of anatomy. It is believed that he must have performed his dissections in Alexandria, Egypt, and that he was associated with Herophilus in this work. His study of anatomy led him to change his views with regard to several matters. For example, he had always previously taught that the nerves originated in the dura mater and not in the brain itself; but, after he had carried on these more careful anatomical studies, he admitted that he had been in error, and that the brain was the real source of origin of the nerves. He never discovered, however, that he was equally wrong when he taught that the arteries contained air, or some sort of gaseous substance, instead of blood.

Erasistratus, it is believed, wrote a large number of treatises, but not one of them has come down to our time. Galen, however, has preserved for us a number of fragments of these works. A. H. B.

Erepsin is an enzyme that has the power of splitting proteoses, peptones, and polypeptides into both mono- and diamino acids. It has no action upon native proteins with the exception of casein. It is assumed that it is responsible for the final digestion of substances arising in gastric and pancreatic digestion of protein. Erepsin is found in the mucous membrane of the small intestine and in the intestinal juice, the former appearing to contain more enzyme than the latter. Similar enzymes have been obtained from the pancreas and from tissues of invertebrates. In plants also enzymes have been found capable of producing effects similar to those of erepsin. On heating to 59° C. erepsin becomes inactive; its best action is obtained in alkaline media and in faintly acid solutions it shows hardly any activity. FRANK P. UNDERHILL.

Ergota.—ERGOT, U. S. P.; *Secale cornutum*, Ph. G.; *Ergot de Seigle*, Codex Med., *Fungus Secalis; Mutterkorn; Spurred Rye*, etc., consists of the sclerotium of *Claviceps purpurea* (Fries), Tulasne (Fam. *Hypocreaceæ*), replacing the grains of rye, *Secale cereale* Linn. Our Pharmacopœia prescribes that ergot should be only moderately dried, preserved in a closed vessel, chloroformed occasionally to prevent the development of insects, and rejected as unfit for use when more than a year old. These directions are quite likely to be changed, for it is now a well-established fact that if ergot is thoroughly dried, and kept so, it can be preserved for years without deterioration. This remarkable parasite is developed in the flowers of several cultivated grains and of a considerable number of wild grasses, germinating upon the ovaries, which it aborts and finally destroys, and growing in the place of these organs like some monstrosity of the flowers themselves. It attains to a sort of maturity as the grain ripens in the fall, and in this condition remains quiescent until the following

season, when, if in a suitable situation, as upon the surface of damp ground, it produces spores in time to attack the blossoming grasses and grains of the succeeding year. It is this resting-stage which constitutes the "sclerotium."

The first noticeable evidence of the presence of this fungus in a spikelet, say of rye or wheat, is a sticky, unpleasant-smelling, very sweet, liquid exudation from the interior of one of the flowers, which accumulates in considerable quantity, and may even drop off or run down the stem. It consists mostly of some sort of sugar, and is probably a decomposition product of the affected pistil. Like similar results of the irritation of vegetable tissues by other fungi, as well as by aphides, etc., it is known as "honey dew," and designated the "honey dew of rye." It is a certain sign that ergot will follow. Ants and beetles are fond of it, flock to the ears where it is to be found, and as it contains cells capable of developing into ergot in other flowers, they assist in spreading the blight. Bees are said to avoid it. A soft, spongy or cottony, mold-like tissue, consisting of long, fine, weak filiform cells, felted together at this time, envelops and permeates the ovary; as it grows the latter becomes disorganized and disappears, and the *mycelium* of the ergot, as this structure is called, takes its place. In a short time after, a very redundant and much wrinkled layer of perpendicular cells covers the surface of the mycelium, and produces innumerable minute oblong false spores (*conidia*), which are discharged into the adhesive "honey dew" just mentioned. These are capable of reproducing the plant, and are the first method of propagation. In this stage it was at one time considered to be an adult and perfect plant, and named *Sphacelia segetum* (Léveillé, 1827). A further development next takes place in the formation and growth of the *sclerotium*. This begins as a condensation of tissue at the base of the "sphacelium" just described, the cells of which become shorter and thicker-walled, as well as more closely packed together. The mass becomes firm and brittle as it develops, the outer surface assumes a purple-black color, and it finally grows to a long spur-like, curved, irregularly cylindrical body protruding half its length or more beyond the plumes and paleæ of the rye. The "sphacelium" atrophies as the sclerotium grows, and is carried up on the apex, as are also any remains of the unfortunate pistil. When the ergot is fully grown and gathered, scarcely any traces of either of these are to be found. At this stage ergot was also considered a distinct plant from the above, and it received separate names (*Sclerotium clavus* De Candolle, 1816, etc.). The growth of the first season terminates with the *sclerotium*, but in the early summer of the next year several minute globular heads raised upon stalks, half an inch or more in length, and looking like miniature "toadstools," grow from the sides of this organ and bear, in numerous cavities (*perithecia*), a multitude of groups of long and slender spores (see Fig. 2094). These spores, applied to the flowers of suitable grasses, are capable of reproducing the whole series of forms described above, and complete the life history of the fungus. It is interesting to note that this stage of claviceps was also known long before its connection with the others was made out, and it was described and named by several authors (*e.g. Sphæria, Cordiceps*, etc.)

Fig. 2093.—Ear of Rye with two Ergots. Natural size. (From Luerssen.)

The first botanist to follow the course of this plant through all its changes was M. Tulasne, who gave it its present name, and finally published his report upon it in the *Annales des Sciences Naturelles* for 1853. His investigations were so thorough, and his illustrations so fine, that but little has been added to either, so far at least as the botany of ergot is concerned.

Habitat.—*Claviceps purpurea* is found in most temperate countries where the grains and grasses upon which it flourishes grow. It is, however, much less abundant in this country than in Europe, and there it occurs most generally in the warmer and moister countries. It is gathered in Central Europe, and especially in Spain and Central and Southern Russia. It is an incidental product of agriculture, and is sorted out from the grain at the harvest with the double purpose of collecting the ergot and of removing its baneful influence from the grain. Ergot of wheat is occasionally saved; it is shorter and thicker than that of rye, and medicinally equally good.

History.—Ergot has long been known as a blight upon grain and as a poison, but its medicinal history is comparatively modern. It appears to have been used by the peasantry, in some parts of Europe, in childbirth as much as three hundred years ago, and is mentioned by several authors of the sixteenth and seventeenth centuries in this connection; but its formal introduction into modern medicine is due to the efforts of Dr. Stearns, of New York, in the early part of the last century.

Fig. 2094.—Ergot in its Final Fructifying Stage. (From ——.)

Description.—The above-described "*sclerotiums*," which constitute ergot, are from one and one-half to three centimeters (one-half to a little more than one inch) long and three millimeters (one-eighth inch) thick, oblong, tapering toward, but obtuse at both ends, triangular-cylindraceous, the sides unequally grooved; externally purple-black, nearly smooth; internally whitish, with purplish tinge or striæ, the fracture short usually, except in the Spanish variety, odor peculiar, disagreeable, especially upon trituration with potassium or sodium hydrate T. S.; taste oily and disagreeable. It molds and spoils rather easily, and should be kept fresh and dry. It should not be broken or ground until needed for use. Microscopically it consists of closely entwined, elongated, thick-walled cells containing an abundance of oil drops. Of the commercial varieties, Russian and Spanish ergots are commonly preferred. Small or medium-sized grains are believed to be superior to very large ones.

Composition.—Ergot has been repeatedly examined within the past half-century, with the result of exhibiting a more and more complex composition with each

successive investigation. Being a parasitic fungus, it is responsible for the presence, not only of the compound of its own manufacture, but for decomposition products from the tissues of its host. These products are remarkably unstable, and also difficult of purification, so that many of the so-called proximate principles which have been isolated and described are either artificial, resulting from the treatment, or mixtures of two or more substances. To add to this confusion, manufacturers have been liberal in supplying pharmaceutical preparations, under trademarked names, which were supposed or claimed to be active constituents. In general, the constituents may be grouped respectively as water-soluble and alcohol-soluble. The latter are the alkaloids and sphacelic acid and sphacelotoxin. The former are various compounds of the latter. In addition to these active constituents, we have a number which, although inactive therapeutically, are of importance from a pharmaceutical standpoint. Of these, the fixed oil is the most important. It sometimes exists to the extent of thirty per cent. or more. It is very prone to decomposition, as a result of which decomposition of the other constituents quickly supervenes. The only perfect protection against this accident is to dry the ergot and keep it dry and protected against the atmosphere. With this rancidity of the oil, due to dampness, myriads of mites develop upon the ergot, coating the grains with a very fine, dust-like powder. Such ergot is unfit for use.

The principal alkaloids are cornutine (Keller), cornutine (Kobert), ergotine, ergotoxin and tyramine. Each cornutine has been claimed by its discoverer to be the most important active constituent of ergot, while declared by others to be not a definite chemical body. While the latter statement is probably true, it is certain that Keller's cornutine comes as near to representing the valuable properties of ergot as anything ever isolated. Ergotoxine is also said to yield highly satisfactory results. This is a hydrate of ergotine, which latter is not very active. Tyramine belongs to the cadaveric class of alkaloids and cannot be regarded as a normal vegetable constituent. Sphacelic acid and sphacelotoxin are closely similar, one being apparently an impure form of the other. Both are highly active and, combined with other substances, become water-soluble, although then less active. Thus, secalintoxin is a water-soluble compound with the inert constituent seccalin. Salts of the alkaloids are similarly water-soluble and less active. A host of other substances have been described, an account of which would be wholly unprofitable in this article. The practitioner cannot expect to get the same results from the administration of any constituent as from that of the standardized fluid extract, unquestionably the best of all forms of administration.

From the foregoing it will be readily seen that ergot is not amenable to chemical assay for the determination of its quality, although, because of the highly varying action of different commercial samples, to some extent in kind as well as in degree, there are few drugs more in need of it. Under these circumstances, Houghton's method of physiological assay becomes of great interest. This consists in feeding the drug to fowls, then noting the extent and promptness of the discoloration of the comb, and finally rejecting any ergot which does not produce an effect reaching to a fixed standard. To this method various *a priori* objections have been urged by those who have not resorted to the very simple expedient of ascertaining the practical results of the method, which appear to have been the putting of an end to complaints of irregular or uncertain action. Other methods of physiologic standardization are either unreliable or impracticable.

Action.—The action of ergot and of its constituents is extremely complicated and can as yet by no means be said to be understood, though great progress has recently been made. We have now a fair knowledge of its practical effects as a drug. Our lack of knowledge relates mainly to the different effects produced by the different constituents, with the resulting disadvantage that we are unable intelligently to administer different preparations to meet special cases. The two most important effects of the drug are the prolonged contraction of the arteries, and the physiological strengthening of the natural rhythmic contractions of the uterus. Both of these effects are of complex origin. In the production of the former effect, the drug acts chiefly by stimulating the vasomotor centers, to a less extent by acting directly upon the artery. To get the full arterial effect, preparations of ergot should be given by the mouth, although hypodermic injection produces a more prompt result. The net effect is a powerful, prolonged contraction of all the smaller arteries, with a consequent marked increase of blood pressure, going on, *pari passu* with the administration of the drug, to dry gangrene and loss of the extremities, and to extravasation of blood into the viscera.

The effect upon the uterus is primarily due to spinal stimulation, but there is evidently also a direct action upon its walls.

Upon the intestine, the effect of ergot is to increase peristalsis, but at the same time to diminish secretion, as is true of the secretions generally, due to diminished arterial supply.

Uses.—Ergot is chiefly employed as an ecbolic, being given in the later stages of parturition, especially to secure the complete emptying of the uterus, and to check hemorrhage. Formerly it was given at one stage earlier, to favor the expulsion of the placenta, but this practice is now generally discouraged. Against these views are still those of some excellent practitioners who recommend the early moderate use of ergot to promote labor.

Next to this use of ergot, that for checking internal hemorrhages, especially of dysentery, may be considered the most extensive. Its use has been found favorably to affect aneurysms. It is also very largely employed in the relief of headache resulting from prolonged mental activity and excitement, and whenever congestion exists. It also gives marked relief to conjunctivitis of a similar character.

Finally, it will frequently be found to do good service as an aphrodisiac, although in many cases it will fail.

Preparations and Doses.—The unofficial preparations of ergot are exceedingly numerous, and the practitioner should treat them with great conservatism, owing to the possible serious change in property resulting from slight differences in the mode of extraction. Since some active constituents are alcohol-soluble, others water-soluble, both solvents should be used in the extraction. The official fluid extract, especially if having been found to meet a satisfactory physiological test, made with diluted alcohol, and with the addition of two per cent. of acetic acid, answers every requirement. It may be given in doses of fl. ʒ ss.–i. (2.0–4.0); the wine of fifteen-per-cent. strength may be given in doses four or five times as large; the extract ("ergotin") is considerably used in doses of gr. v.–xv. (0.3–1.0). Recently, excellent results have been reported from the use of ergotoxine phosphate, about two and one-half milligrams of which corresponds to 1 c.c. of the fluid extract.

Henry H. Rusby.

Erichsen, Sir John Eric.—Born in Copenhagen, Denmark, in 1818. He studied medicine in London, and was Professor of Surgery in that city from 1850 to 1875. Before his death, on September 23, 1896, he had become quite celebrated as a surgeon. He owed this celebrity in large measure to his great work on surgery—"The Science and Art of Surgery"—

a book which passed through ten editions. Of his other published writings the following deserve to be mentioned: "Pathology and Treatment of Asphyxia" (awarded the Fothergill Gold Medal); "Railway Injuries of the Nervous System," London, 1866; and "Hospitalism, and the Causes of Death after Operations and Surgical Injuries," London, 1874. In 1895 he was made a baronet. A. H. B.

Erigeron.—Fleabane. Several species of the large genus *Erigeron* L. (fam. *Compositæ*) have been official and largely used in medicine. Because of their inferiority, they gradually disappeared from use, with the exception of one, known as *E. Canadense* L. Botanists now accord this generic distinction from the others. It is known as *Canada Fleabane, Colts-tail, Pride-weed, Bitter-weed, Blood-staunch*, etc., the leaves and flowering tops of *Leptilon Canadense* (L.) Britton. The plant is a very tall and robust annual weed, exceedingly common and abundant in the eastern United States and Canada, and widely distributed over the entire world, in tropical as well as temperate regions. The hairy stem is from two to eight feet high, erect, slender, simple up to the inflorescence and densely clothed with ascending or nearly erect lanceolate leaves, from three to six inches in length. Above this the tawny, fluffy paniculate inflorescence strongly suggests the appearance of a colt's tail and gives the name. The drug contains much tannin, about one per cent. of the volatile oil next considered, and an amaroid. It is not remarkable that this should be one of the most valuable of all household remedies for controlling severe attacks of serous diarrhea, as its oil powerfully stimulates the sympathetic abdominal nerves, while its tannin astringes locally. It is at the same time a good aromatic bitter. The country practice of giving it in infusion, in doses of ʒ ss.–i., is improved upon by giving fl. ʒ ss.–i. of the fluid (2.0-4.0) extract.

Oleum Erigerontis (U. S. P.).—Oil of erigeron is a volatile oil distilled from the last, of a pale-yellow or brownish color, a peculiar, pleasant odor, and a warm, pungent taste. It has a specific gravity of about 0.850, increasing with age to about 0.890, and consists chiefly of dextrogyrate limonene. It is quite a different substance as distilled, even when fresh, from what it is in the plant, as there is a portion which is destroyed by even a moderate heat. This fact, together with the absence of the other constituents of the herb, indicates the error of substituting the latter by the oil. The oil is, however, active. It belongs to the astringent class of volatile oils, acting like oil of turpentine in this respect, but without its irritating properties. It is administered for the same purposes as fleabane, and for the control of hemorrhages of the bowels and uterus, and for gonorrhea. The dose is ♏ v. to xv.(0.3-1.0). Henry H. Rusby.

Eriodictyon.—Yerba Santa. "Consumptive's weed," "Mountain balm," etc. The dried leaves of *Eriodictyon Californicum* (H. et A.) Greene (fam. *Hydrophyllaceæ*). A very pretty evergreen shrub, growing on the western side of the United States and in northern Mexico, in gregarious clumps and patches in barren soils and among rocks. The drug is thus described: Usually much broken; blade narrowed into a very short and broad petiole, five to twelve centimeters (two to five inches) long and rarely exceeding three centimeters (one and one-fourth inches) in breadth, oblong-lanceolate, gradually tapering to an acutish point, most irregularly serrate- or crenate-dentate, thick and brittle, or flexible in a damp and warm atmosphere, the margins more or less incurved; upper surface yellowish-green, more or less resinous, smooth, the veins somewhat impressed; lower surface whitish or yellowish-white, with finely and conspicuously reticulate dark veins, densely but very shortly tomentose; odor somewhat aromatic, strongly balsamic if heated in the closed hand; taste balsamic, sweetish, somewhat tea-like.

The principal constituent of this drug is its ten to twelve per cent. of resin, divisible into two parts, one of which, constituting its chief bulk, possesses the property of precipitating quinine from its salts. It also contains volatile oil, ericinol, sugar, and the peculiar body *eriodictyonic acid*, which in some respects resembles tannin.

Yerba santa has a local reputation on the Pacific slope for coughs, colds, bronchitis, and phthisis, a reputation which is shared by many other resinous substances and has some foundation. It is also a pretty good vehicle for the administration of quinine, whose taste it, like liquorice or glycyrrhizin, covers pretty well. Of the official fluid extract, ♏ xlv.–lxv. (3.0–4.0 c.c.) may be given for coughs. A syrup, as a vehicle for quinine, is sometimes prepared.

Henry H. Rusby.

Eristalis.—A genus of flies. The "rat-tailed larvæ" of these insects sometimes cause myiasis by infesting the human intestine. See *Insects, Parasitic.*

A. S. P.

Eructation.—Belching. This is defined by some as the audible emission of gas from the stomach through the mouth. Audibility is, however, not a critical point, and the gas may issue through the nostrils. Eructation is also usually considered to include the raising of small quantities of liquid or semi-solid matter from the stomach, along with the gas, and without nausea and the expulsive effort of vomiting. The term should, however, not be extended to include true vomiting, nor the puking of infants, and scarcely the habitual raising of small quantities of gastric contents without notable amounts of gas—merycism. Eructation is often confused with and sometimes complicates true aërophagia (*q.v.*). While it is proper to include the raising of liquid and semi-solid matter with eructation, and while such matter may be raised without gas in noticeable quantities, it is better to restrict the term *eructation* to those instances in which the regurgitation is due to gas pressure and to use the term *water-brash* for cases in which the liquid and semi-solid contents "return" without nausea. It is not, however, always possible to draw hard and fast lines between the conditions.

Regarding the liquid and semi-solid portions of an eructation, it is only necessary to say that their consistence, chemical characteristics, etc., will depend upon the ingesta, the period of digestion at which they are raised, whatever pathologic condition may affect the stomach, and the intermixture of mucus and saliva which is usually enough, with reference to their small amount, materially to affect conclusions as to the actual state of gastric digestion.

The first stage of deglutition is voluntary and a large, hastily swallowed bolus is apt to contain considerable air. There seems to be, also, in some individuals, such a conformation of the fauces and pharynx, that incorporation of air with the bolus is inevitable. In any case, some air is swallowed with food and drink. Whether eructation occurs after a meal or not, depends upon intragastric tension, gastric motility, and the relative tonicity of the cardia and the pylorus. It does not appear that the tonicity of the cardia and the pylorus bear a definite relation to each other, either directly or reversely and, indeed, the competence of the cardia seems to be a matter of idiosyncrasy. Thus, granting that the stomach is over-distended with gas, with due regard to the space available beyond what is filled with solid and liquid contents, eructation is a conservative process but

one that does not necessarily occur with a uniformity justifying the use of the term physiologic.

Conservative eructation may also occur after the ingestion of beverages charged with carbon dioxide or other gas. It is doubtful, in spite of theories formerly accepted as to extrapulmonary respiration, whether the stomach discharges carbon dioxide or other gas into its cavity, by either osmosis or cellular activity, to any appreciable amount.

Eructation is generally ascribed to the formation of various gases, such as hydrogen, carbon dioxide, and methane, and volatile organic products by fermentation. Strictly putrefactive processes, analogous to those of the large intestine, may also occur in the stomach, in certain cases of achylia, especially with cancer or other lesion in a state of necrosis. So, too, with relaxation of the pylorus, actual or relative to intestinal gas pressure, gases due to putrefaction in the intestine may reach the stomach and cause eructation. It should be borne in mind, however, that incubation experiments with either stomach contents or feces, rarely yield any such amount of gas as is noted in eructation, limiting our attention to eructation at a sufficient time after a meal to exclude the conservative discharge of swallowed air, and excluding from consideration eructation due to aerated beverages. For example, stomach contents having even a small proportion of free hydrochloric acid, rarely yield more than two to three per cent. of gas by bulk, even after twenty-four hours incubation and the same is true of ordinary formed feces. Even in achlorhydria, fifty per cent. of gas by bulk is high. Speaking generally, therefore, the fermentation theory does not account for more than a small proportion of cases of marked eructation nor does it usually account for the amount of gas which can be collected, in a given case; especially if we consider the comparatively brief space of time allowed for fermentation as compared with the twenty-four-hour standard for incubation *in vitro*. However, in ischochymia, even in the presence of moderate amounts of free hydrochloric acid; in cases in which fermentative or putrefactive bacteria have developed to an unusual degree in the stomach; and in cases in which the ingesta are impregnated with gas-producing germs, the fermentation theory of eructation unquestionably holds good, and it may be a supplementary factor in many other cases. In rare instances, especially when much cellulose has been ingested, there may be so much formation of hydrogen and methane, that the eructated gas is inflammable.

In diabetes and other conditions of disturbed metabolism, acetone and its congeners may be present in the eructations as well as in the breath, imparting a characteristic odor. It is well known that various volatile substances occur in eructated gases, arising from foods and drugs but these are quantitatively unimportant.

The maximum immediate production of gas in the alimentary canal if not the maximum altogether, occurs from the effervescence, with liberation of carbon dioxide, due to the interaction of acid gastric contents with the secretions of the pancreas, liver and intrinsic intestinal glands, all of which contain alkaline carbonates. Barring putative failure of carbonates in these secretions, and states of achlorhydria without fermentation acidity to any great degree, this action is inevitable. With relaxation of the pylorus, which is liable to occur in any condition, though comparatively seldom in hyperchlorhydria, gas thus produced is probably the most frequent cause of eructations not due to swallowed air nor to aerated beverages and excepting, also, the artificial addition of a carbonate to acid gastric contents by swallowing.

Differential Diagnosis.—Eructations are often accompanied with liquid or semi-solid stomach contents. Conversely, true vomiting usually brings up some air from the stomach. Observation of the case will usually suffice to make a differential diagnosis though there may be individual cases in which the classification is doubtful. Aerophagia may be distinguished by noting the alternation of inspiratory reflexes distending the esophagus and of expulsive efforts; by the continuance and amount of the expulsions which far exceed the possible limit of true eructation; by auscultation over the stomach to determine whether the inspiratory efforts admit air beyond the cardia. Obviously, however, there are cases of aerophagia in which air actually passes the cardia so that its expulsion conforms technically to the definition of eructation and an aerophagic seizure may not only be accidentally accompanied by true eructation but the motor phenomena involved favor true eructation of whatever gas may be in the stomach, as well as the suction of gas from the intestine into the stomach.

Treatment.—The eructation of swallowed gas usually occurs during or shortly after a meal and a similar statement may be made concerning the eructation of gas from aerated beverages or that due to swallowing sodium bicarbonate. The patient can usually train himself so as to minimize the audibility of eructation and to reduce the amount of gas swallowed with food and drink by careful habits of eating. But, as stated, certain cases seem to be due to peculiarities of conformation of the fauces and pharynx. The eructations themselves are conservative. The special annoyance of entry of eructated gas and sour particles of stomach contents into the nares cannot always be remedied.

The microscopic examination of the gastric contents or of the wash water from an empty stomach, the chemical determination of organic acids, the incubation test and the more elaborate methods of gas analysis, serve to determine fermentative processes. Restriction of diet, lavage, catharsis, internal antisepsis, digestants, summarize the treatment.

The odor of the gas eructated may be of diagnostic value in cases of acetonemia of any kind, and may also serve to distinguish approximately between fermentation and putrefaction. The indications for treatment are too remotely related to the eructations to be considered here.

If eructations of any large amount of gas occur in a case of hyperchlorhydria, at a sufficient length of time after a meal to exclude swallowed air, effervescence with the carbonatic intestinal secretions may be inferred, along with relative relaxation of the pylorus. Allowance must be made, however, for the use of sodium bicarbonate by the patient, as well as for the complaint of eructations which are found on close questioning or observation to be non-existent or slight, and due to a false interpretation of the irritation of the highly acid gastric contents. True eructations are not usually encountered in hyperchlorhydric cases, probably because of the spastic state of the pylorus. When they occur, they need no special treatment beyond the sedative and still-alkali treatment of the hyperchlorhydria itself.

There are cases in which the gastric secretion and motility are below par and in which both pylorus and cardia are apparently relaxed, leading in turn to entrance of intestinal gas into the stomach and its eructation. In such instances, there is an indication for strychnine. In other cases, there seem to be discordant indications which cannot be adequately met, except by a general attention to diet, hygiene, etc.

Eructations are often the first indications of seasickness and, analogously, they may occur as a reflex from constipation, peritonitis from a variety of focal inflammations, peritoneal irritation from ileus of various types, etc. In these cases, there is probably no great amount of gas in the stomach but the reflex

stimulation of gastric peristalsis forces out the ordinary residual gas. In such instances, the eructations are to be considered, not as an indication for direct relief but as a warning symptom of considerable value.

A. L. Benedict.

Erxleben, Dorothea Christian.—The first woman in Germany to receive the degree of Doctor of Medicine. Dorothea Leporin was born at Quedlimburg, in Prussian Saxony, on November 13, 1715. Although at an early stage of her education she studied philosophy and medicine she made no direct use of this training until she had reached the age of thirty-nine. In 1742 she married J. Christian Erxleben, deacon of the Nicholas church in her native town, and for several years afterward her time was largely occupied with domestic duties. In 1754, however, she passed successfully the regular examinations at the University of Halle and was given the degree of Doctor of Medicine. From that time onward she engaged in the practice of her profession and met with great success. She died June 13, 1762.

In addition to her inaugural dissertation Dr. Dorothea Erxleben published the following treatise: "Gründliche Untersuchung der Ursachen die das weibliche Geschlecht vom Studiren abhielten," Berlin, 1742 (reprinted at Frankfurt and Leipzig in 1749).

A. H. B.

Erysipelas.—*Definition.*—Erysipelas is an acute infectious disease characterized by inflammation and brawny induration of the skin, with a tendency to peripheral extension and accompanied by the constitutional manifestations of a severe toxemia.

Bacteriology.—The bacterial origin of this disease was established by Fehleisen who described the so-called *Streptococcus erysipelatis*, which however has now been shown to be identical with the hemolytic *Streptococcus pyogenes*. Mixed infections with the *Staphylococcus albus* are frequent in the suppurative cases.

Portal of Entry.—Wounds of the skin, operative or traumatic, abrasions, excoriations, and leg ulcers afford the visible source of infection in a number of cases. However, the large majority of all cases commence on the face and without any sign of external injury. These so-called "idiopathic" cases usually, if not always arise from a preceding streptococcus infection of the mucous membrane of the nose, throat, or ear. Erosions of the buttocks and vulva, infections about the umbilicus, and eczema frequently give rise to erysipelas in infants.

Terminology.—We might well discard many of the older descriptive terms, some of which are confusing, others merely indicative of certain phases or complications of the disease; *e.g.* "idiopathic," "traumatic," "surgical," "fixed," "vague," "serpiginous," "vesicular," "pustular," "gangrenous," "phlegmonous," "E. neonatorum," etc. However there remain several types which merit separate mention.

1. *Facial Erysipelas*, the type which represents from eighty to ninety per cent. of all cases, deserves special description because of its strong tendency to limit its extension to the integument of the face, ears, scalp, and neck down to the collar line.

2. *The Migrating Form* (erysipelas migrans or ambulans) includes practically all other cases, whether the starting-point be on the face, on the trunk, or on an extremity, but where there is no special limitation; on the contrary, there is a decided tendency to consecutive involvement of more or less of the whole surface of the body and extremities.

3. *Erysipelas* has been described as affecting the *mucous membranes* of the entire respiratory and alimentary tracts. These cases are very rare and difficult to identify unless the extension has been from a visible skin lesion. Fatal edema of the glottis resulted in one of my cases. A streptococcus infection of the nose, ears, or throat [illegible] antecedent of facial erysipelas, but one would hardly call these cases erysipelas of the mucous membranes for there is nothing characteristic of erysipelas about them until the typical skin lesion develops.

4. Other forms such as "phlegmonous," "gangrenous," etc., are rather to be considered complications or sequelæ.

Etiological Factors.—*Sex.*—At v. Ziemssen's clinic, among 700 cases, seventy-three per cent. were females. In America, Anders found a "preponderance of males" among his cases, and in my experience with 1,000 cases at Bellevue Hospital there were sixty-five per cent. males and thirty-five per cent. females, a disproportion which I have attributed to the greater exposure to inclement weather, greater addiction to alcohol, and greater liability to wounds on the part of the men.

Age.—In 1,894 cases examined by Anders and in 1,000 cases of the writer's, the age incidence corresponds very closely.

The writer's analysis of 1,000 cases is as follows:

Infants under 2 years	[illegible] per cent.
From 2 to 15 years	[illegible] per cent.
From 15 to 20 years	5 per cent.
From 20 to 55 years	82 per cent.
Over 55 years	[illegible] per cent.

Season.—The late winter and spring months, especially February, March, April, and May, damp months with changeable weather, develop from two to three times as many cases as do the summer months, owing to the prevalence of infections of the nose and throat induced by the weather conditions, and to a lowered resistance resulting from the confinement of a winter's work. A sudden cold snap will fill the wards to overflowing.

Susceptibility as a result of previous attacks is a well recognized factor, and in my experience over fifteen per cent. of the patients had had from one up to ten previous attacks. Anders found 8.6 per cent. of such cases among 450 cases studied. Inherited susceptibility has not been proven.

Antecedent Conditions.—Some point of entry for the infection is essential to the development of erysipelas and this subject has already been considered.

Lowered resistance to this streptococcus infection may be the result of nephritis, tuberculosis, heart disease, hepatic cirrhosis, and other asthenic conditions; but in importance in this regard alcoholism easily ranks first in my experience. Faulty hygienic surroundings and personal habits are often predisposing factors.

Pathology.—Erysipelas is essentially a streptococcus skin infection, with the inflammation located in the true skin and marked by infiltration with leucocytes, by edema, by proliferation of the fixed connective-tissue cells, and with the streptococci commonly to be found in the lymph spaces of the advancing border and in the blebs on the surface.

Extension to the subcutaneous tissues is more commonly attended by suppuration, but suppuration occurs in less than ten per cent. of the cases, which is remarkable when we consider the character of the infecting organism.

The inflammation tends to spread peripherally while recession and recovery are taking place in the center.

Symptoms.—*Incubation.*—This period is usually short, not exceeding one or two days, or from fifteen to sixty hours. Some writers, however, state that the incubation period averages from three to ten days, and they describe enlargement and tenderness of the submaxillary lymph nodes as occurring from one to three days before the skin lesion.

We have never found this glandular involvement

in any form of erysipelas frequently enough to be of any significance; and certainly the early enlargement above mentioned must be related rather to the nose or throat infection which may precede the erysipelas.

Onset.—The symptoms of the facial type of erysipelas, which includes about eighty-five per cent. of all cases, are so characteristic of the disease that their description is classic.

With or without prodromal symptoms of coryza, angina or wounds, the real onset is with a pronounced chill or chilliness and a rapid rise of temperature to 102° to 105° F., accompanied by general malaise, headache, anorexia, nausea and by vomiting (in more than half of our cases).

Within a few hours or upon the following morning, the patient is aware of a burning sensation and of tension, pain, and tenderness over a small area about the site of infection, which in facial cases not due to wounds is usually at one side of the bridge of the nose over the lacrymal sac.

Rapidly, within a few hours, this area spreads down over the cheek and across the bridge of the nose and very frequently there is symmetrical involvement of both cheeks, forming the "butter-fly" pattern. The marked edema and swelling of the eye-lids may distort the features beyond recognition.

A few mild cases may remain thus limited to one or both cheeks but there is a tendency to contiguous extension laterally to the ears, upward to the forehead and backward through the scalp.

The sides and back of the neck may be involved, but only rarely does the lesion extend below the chin in front, or the collar-line behind. The extension is peripheral, continuous, and absolutely regardless of the direction of the lymphatic currents.

Involvement of the hairy scalp is most painful, owing to the great edema which takes place in the unyielding integument.

Lesion.—The area affected varies in color from a bright scarlet to a bluish red and rarely it may be hemorrhagic. The redness is that of very active congestion and disappears upon pressure only to reappear instantaneously. The surface is smooth, shining, tense, and hot and does not pit on pressure. The advancing margin is distinctly elevated and brawny and well demarcated from the surrounding tissues.

Blebs.—In a great many cases and characteristic of erysipelas blebs appear on the surface usually within one to two days. The clear serum from the blebs often yields the hemolytic streptococcus, but it may be sterile, or contain staphylococcus albus as well as streptococcus; at times the blebs become pustular.

Desquamation.—In from three to five days the surface of the older areas loses its tense, shining appearance, the blebs dry and desquamation of the epithelium begins and is continued for a week or more even after abatement of both local and constitutional symptoms; only rarely is there no evident desquamation.

Migrating Erysipelas.—Of the cases which start on the face only about five per cent. extend below the neck and become generally migrating, advancing with an irregular scalloped margin with tongue-like projections, down the back, over the whole trunk and even down the extremities. In infants, no matter where the initial infection, and in all cases where the process has started on the extremities or on the trunk, the migrating form is rather to be expected. As the erysipelas passes over the trunk and down the extremities, the advance from day to day tends to observe a rough bilateral symmetry. On the trunk the margin of the lesion is less distinctly elevated, less red, and less painful than on the head or on the extremities.

Febrile Movement.—Counting the days from the onset until the rectal temperature remained at or below 100° F., in 800 cases (treated merely symptomatically) the writer found the average duration as follows:

Uncomplicated facial cases...	500.	Average fever 6.77 days
General body or migrating...	56.	Average fever 14.44 days
Leg cases	33.	Average fever 10.88 days
Complicated cases.....	211.	Average fever appr. 2 weeks.

Thus one week for facial cases and two weeks for migrating cases may be considered as the average duration.

Of the facial cases, eight, or one per cent., were afebrile throughout and many were of only three or four days' duration; whereas many were much longer, *i.e.* ten, fifteen, and twenty days and in relapsing cases even longer.

Characteristically the temperature curve is marked by its irregularity, with considerable daily remissions, and defervescence is by lysis; however, not a few cases show a temperature curve similar to that of lobar pneumonia terminating by definite crisis.

Maximum temperatures of 103° to 105° F. are usual except in the mildest cases. After abating, any rise in temperature is apt to indicate a recrudescence or an extension or developing suppuration.

At times the local lesion continues to spread after the temperature remains normal, and, *vice versa*, there may persist some irregular fever for days after the local manifestations have entirely subsided.

Delirium is very common in the cases with severe face and scalp involvement, and occurs at the height of the febrile movement. In alcoholics, delirium tremens is prone to develop.

Leucocytosis.—A polymorphonuclear leucocytosis of from ten to twenty thousand is usual.

Blood cultures have almost universally failed to show the streptococcus except in the suppurative and septicemic cases.

Complications and Sequelæ.—With some regard to relative frequency the complications may be stated as follows: suppuration (which occurred in over eight per cent. of our cases) was found most often in the eyelids, the scalp, and the legs; conjunctivitis; delirium tremens; pneumonia; arthritis; septicemia.

Nephritis was usually only of the transient febrile form. Extension to the mucous membranes may cause blocking of the nose, angina, otitis media, and rarely edema of the glottis.

Endocarditis has been reported. Gangrene of the skin, especially of the scrotum, may occur. Other complications, still more rare but which have been encountered, are: blindness from orbital suppuration or panophthalmitis; septic meningitis; pericarditis; periosteitis, and osteomyelitis, etc.

As a sequel to severe scalp involvement there may occur temporary alopecia.

Diagnosis.—This is seldom difficult in the typical facial types if one considers the violent onset, intense systemic reaction, and the red, shining, hot induration of the skin lesion with its irregular, elevated, indurated margin and the tendency to bleb formation and later desquamation. But the diagnosis may be very difficult and often impossible in those cases which start from an infected wound and in all leg cases.

Many cases of typical simple cellulitis of the leg or arm are mistaken for erysipelas because of the accompanying lymphangitis; but in erysipelas the border should be more distinct, and its irregular, tongue-like margin advances just as easily counter to the lymphatic flow as upward with the lymphatics.

Exudative erythema is not unlike erysipelas, at times, but is usually multiple. Other skin lesions and neoplasms will lack either the systemic or some of the local symptoms of erysipelas.

Prognosis.—Uncomplicated erysipelas is a self-limited disease with tendency to recovery, and the mortality should never exceed five per cent.

However, in general hospital cases with many complications and many alcoholics, the mortality rises to 6.57 per cent. (in 1,810 cases of Anders) or even to

11.6 per cent. in 800 cases at Bellevue in my service. Infants under one year have high mortality but not so high as has been reported by some writers, *i.e.* 75 per cent. to nearly 100 per cent.; indeed in fifty-two of my cases there were only twenty-two deaths or 42 3 per cent. In fifty-six general body cases, many of them being infants, the mortality was nearly fifty per cent.

Alcoholism, pneumonia, sepsis, and accompanying nephritis, endocarditis, and tuberculosis greatly add to the mortality. The degree of fever is not of prognostic importance.

Relapses are not uncommon after an afebrile period varying from a few days to several weeks. Any possible immunity conferred by one attack is conspicuously short-lived and inefficient in this disease, and recurrences of erysipelas after intervals of months or years are to be expected in over fifteen per cent. of cases, as is shown by my histories.

Contagion.—Inoculation from one patient to another and from one part of the body to another is clearly possible in erysipelas, but in these days of the aseptic and antiseptic treatment of wounds and diseases, such transference of this disease should not and in my experience does not easily occur. But isolation of these cases in a general hospital is certainly desirable on the ground that all streptococcus cases are undesirable in a surgical ward.

In only four cases out of 1,000 which I have analyzed was there any history of exposure to another case of erysipelas, although most of our cases remain ill at their homes, without isolation, for several days before coming to the hospital, and very many return to their homes while desquamating.

Treatment.—*Medication.*—This should be largely symptomatic, to wit, cathartics, sedatives, stimulants, as the occasion requires.

The claims which have been long advanced for special medication such as iron, quinine, salicylates, pilocarpine, etc., have not been sustained in practice.

Local Applications.—Ichthyol, collodion, phenol (painted or injected), bichloride, iodine, alcohol, picric acid, etc., have failed in my hands consistently to limit or alleviate the disease.

Cold compresses of iced boric acid solution or water, continuously applied to the area affected, are cleanly and soothing, harmless and inexpensive, and accomplish more than do the many local applications which have been vaunted.

For the extremities we employ wet dressings of boric acid or alum acetate.

On the trunk, wet dressings would be uncomfortable and might induce bronchitis or pneumonia and as the lesion here is not so painful, no dressing is required; but picric acid or ichthyol may be used.

Specifics.—Marmorek's and other antistreptococcus sera have failed. Autogenous and stock vaccines made from erysipelas streptococci demonstrated no efficiency in a series of ninety-five of my cases so treated.

Phylacogen was used in twenty cases absolutely without benefit. Excellent results are claimed for the leucocytic extract of Hiss and Zinsser as administered by Dwyer, but further investigation is needed to estimate finally its efficiency.

As in the treatment of pneumonia, so in erysipelas we still await a really efficient treatment; meanwhile, the best methods at hand are comprised in good nursing, generous feeding, symptomatic medication, and cold local applications. Seward Erdman.

Erythema.—The term erythema is a general one for certain diseases of the skin in which there are evidences of hyperemia and passive inflammation. It simply means redness, and is therefore nothing more than a symptom, and, used without a qualifying adjective, has but little definitive value.

The definition of erythema, as given by some authors, is "a localized congestion, accompanied by redness, which disappears under pressure."

Two divisions of the subject are usually made, viz., Erythema hyperæmicum and Erythema exudativum; these are again subdivided according to symptoms.

Erythema Hyperæmicum, or *Simple Hyperemic Erythema*, is that form of the disease which is characterized by various-sized and various-shaped points and patches of redness, exhibiting no evidences of inflammatory exudation.

The patches readily disappear upon pressure.

The causes of the affection are numerous: heat, cold, the presence of irritating substances, as well as certain general systemic disorders.

It occurs both idiopathically and symptomatically.

The *Idiopathic Hyperemic Erythemas* are those which are produced by cold or by heat, by traumatism, or by the application of some irritant to the surface of the body.

If the skin be exposed to any of these agents for a great length of time the condition passes from the simple hyperemic into the exudative stage. Slight sunburn is perhaps the mildest type of hyperemic erythema. Artificial heat may produce the same condition (*Erythema ab igne*). Cold will also produce a certain amount of congestion (*Erythema pernio, chilblain*). Wounds and contusions, pressure of clothing or bandages, also cause a localized erythema.

The *treatment* for simple erythema is upon general lines. If it is caused by pressure of clothing or by the chafing of two opposing skin surfaces (Erythema intertrigo), remove the pressure and apply some soothing dusting powder.

If it has become almost eczematous in character, and the diseased area is covered with a sticky exudation, as is often the case in infantile intertrigo, Lassar's paste, calamine lotion, or any one of the other external applications for eczema, is indicated.

If the erythema is from the external application of drugs, the treatment is obvious; remove the cause.

The *Symptomatic Erythemas* are important, because they so often simulate more serious affections. They generally occur as the result of some derangement of the digestive tract. They may also accompany certain systemic diseases, such as diphtheria, scarlet fever, cholera, uremia, Bright's disease, etc.

The eruption may be found on any portion of the body. The lesions appear in various shapes; patches, spots, rings, etc., small reddish pea-sized spots called roseola, are often seen in the beginning of a syphilitic rash, smallpox, or as an accompaniment of vaccination, and in some cases of jaundice.

The peristent or fugitive flush seen in rheumatism, asthma, goiter, hemiplegia, is an erythema produced by some impairment of the central or peripheral nervous functions.

The symptomatic erythemas occur in both the hyperemic and the exudative varieties; and, as they are more frequently observed after they have passed into the inflammatory stage, to save space they can be more conveniently discussed here, before considering the distinct group of erythema multiforme.

Erythema Diphtheriticum. During an attack of diphtheria, especially if severe, there often occurs upon the thorax and abdomen a diffuse eruption, sometimes extending over the extremities; it may be mottled, punctate, or scarlatiniform in character. The rash usually appears on the second or third day of the disease and should be distinguished from the toxic maculopapular erythema multiforme which appears late in the course of diphtheria.

Since the introduction of antitoxin as a therapeutic measure a form of erythema (serum rash) has been noted it occurs chiefly on the trunk, making its appearance from six to twenty-four hours after the injection. This epiphenomenon is due to anaphylaxis.

Erythema Cholericum. This is a polymorphous, maculopapular erythema seen in some cases of cholera. The eruption first appears on the hands and feet, extending to the forearms, legs, and trunk, and finally to the face. It usually begins early or late in the disease, lasts several days, and disappears by desquamation.

The *Erythema of uremia* is of the maculopapular variety. The first lesions are bright red macules which rapidly change into papules, and are generally upon the extensor surfaces of the hands, forearms, and legs. The eruption may extend over the body, even involving the palms and soles; it runs its course in three or four days and subsides with flaky desquamation. When this cutaneous manifestation is seen as an accompaniment of nephritis the prognosis is grave.

In *Chronic Bright's disease* the erythema consists of bright red macules, generally situated on the trunk, although the neck, arms, and thighs may be involved, and more rarely, the face, hands, and feet; it is accompanied by no subjective symptoms and lasts but a few days.

There is another eruption seen in Bright's disease which is papular throughout. This, I think, is the commoner form. The lesions are large, discrete papules, of a dark red color, generally springing from dry, rough, or scaly patches. The outer side of the thighs and extensor surfaces of the legs and arms are the parts involved.

Erythema Scarlatinoides.—In 1851 Hardy described a cutaneous roseola which closely resembled scarlet fever. He named it erythema scarlatinoides. Later Bazin reported similar cases; he applied to them the term erythema scarlatiniforme. Still later, Besnier gave the disease careful clinical and histological study, and from his researches he considered the proper name to be the one first given by Hardy. Its close resemblance to scarlet fever makes it a disease of considerable importance.

The eruption comes on with slight constitutional disturbance and with more or less elevation of temperature; its advent may be sudden or gradual; it appears first on the chest, as a bright red punctate erythema, and from here eventually spreads over the entire body. Cases have been reported in which it appears as a diffuse general rash. It is often accompanied by burning and itching; the duration, in either case, is short; it soon becomes pale,and in a few days passes off with little or no desquamation. If, however, the attack has been severe, the desquamation may be considerable, the epidermis shedding itself in large patches.

The disease has no specific infectious origin; it is neither contagious nor transmissible. It differs from scarlatina in the absence of the characteristic strawberry tongue and the typical throat symptoms.

Gastric and intestinal disorders seem to be the prominent causative factors. The disease has been observed during the puerperal period and as a symptom of septicemia. It has also been observed in typhoid fever; in which disease it usually occurs at the end of the first or at the beginning of the third week of the fever. The external application of drugs, such as mercury or iodoform, has been known to produce the eruption.

In the *treatment* of the disease such measures should be adopted as the symptoms demand.

Erythema Scarlatinoides Recidivans.—This is a variety of scarlatiniform eruption that tends to relapse, each attack clearing up with considerable desquamation. The disease has been described by the French authors, and many American dermatologists have also reported undoubted cases of this affection.

The term desquamative relapsing scarlatiniform erythema is the name by which the disease is now known. Some of the French writers consider it different from erythema scarlatinoides because of its extremely inflammatory character, and have suggested the term dermatitis scarlatiniformis.

The symptoms as given by Besnier are as follows: It often begins with shivering, lassitude, sore throat, headache, and elevation of temperature. When the rash is at its height the fever will suddenly cease. The eruption lasts for from four to six weeks, and is similar to that of scarlet fever. Desquamation often begins on one part of the body while the efflorescence is present on others.

The etiological factors are numerous: it may be due to external or internal causes; it has been observed in certain diseases such as rheumatism, gonorrhea, toxemia, etc.; mercury, quinine, belladonna, antipyrine are among the drugs which produce this variety of erythema.

One attack predisposes to another, recurrences usually taking place at the change of seasons. While any of the foregoing factors may produce an attack, yet what induces an outbreak in one person will not in another, and attacks in the same subject may be brought about by entirely different causes.

It has been observed that each subsequent manifestation of the disease tends to become milder.

In making a diagnosis, erythema must be differentiated from scarlet fever, which disease it most closely resembles. The principal points to be remembered are: while there may be sore throat at the beginning of the attack it is not so severe as that of scarlet fever, the strawberry tongue is not present, the temperature abates during the height of the rash, the duration of the disease is more variable and prolonged, and, finally, it is non-contagious and tends to relapse.

Erythema Perstans.—This is a type of erythema which has many of the eruptive characteristics of erythema scarlatiniforme, differing in that the rash may persist for weeks, months, or longer. The eruption is symmetrical and is attended by severe subjective symptoms, as pain and itching.

The treatment of this group of erythemas depends largely upon the cause; if it is due to some systemic disease, treat that, or if to external irritation, remove the irritant. Locally, soothing applications will be found useful.

In the perstans variety, Duhring recommends the exhibition of quinine, sodium salicylate, or ergot in full doses.

Erythema Exsudativum Multiforme.—The affections grouped under this general head are characterized by inflammatory changes in the skin, and are in contradistinction to the simple congestive or hyperemic erythemas. As the name implies, the lesions are multiform, and the symptoms and etiology are varied. The French term it *erythème polymorphe.* The general type, erythema multiforme, was clearly described by Hebra; since then the question is constantly brought up whether many of the cutaneous manifestations grouped under this head are not really distinct diseases.

It is an inflammatory affection characterized by reddish or variegated macules, papules, and pustules. The eruption occurs either discretely or in patches, with sharply defined, marginate outlines, and runs an acute course. The patches may be simply erythematous or may consist of maculopapules, papules and vesicles, and, in some instances, of vesicles and blebs.

The lesions pass rapidly through their various evolutions: first, the erythematous patches are red and clearly defined from the surrounding skin; in a few days they begin to assume a purplish or bluish-white color, which disappears upon pressure.

The various shapes, colors, and character of the patches have given rise to the terms circinatum, annulare, papulosum, iris, marginatum, purpuricum, urticans, etc.

The eruption which fades in the center and extends peripherally is termed circinatum. If there are a series of concentric rings formed it is called erythema annulare.

Erythema iris is a rare manifestation of erythema multiforme, and has been described under various names, such as herpes iris, hydroa, herpes circinatus, etc.

Two varieties are most frequently seen: in one the lesions are vesicular and bullous, arranged in clusters and rings; in the other they are vesicular throughout. The degree of redness is marked, assuming in most cases many hues, from which comes the term iris.

The eruption is generally located on the backs of the hands and feet, although it may invade other parts of the skin, even the mucous membranes.

Marginate erythema is simply that form in which the margin is sharply defined. The gyrate and figurate forms are those in which the patches and circles merge together and form fantastic shapes.

Papular erythema is the name given to the disease when the patches consist of papules or maculopapules.

If the erythema is complicated with cutaneous hemorrhages it is called *Erythema multiforme purpuricum;* if with urticarial wheals, *Erythema multiforme urticans.*

Erythema multiforme attacks by preference certain regions of the body; the backs of the hands, forearms, and legs being the localities generally invaded. In some cases the face may become involved. The eruption occurs symmetrically, and the outbreak usually begins first on the hands and fingers. If it attacks the face the first lesions are seen on the forehead.

Cases have been recorded in which the eruption involved the whole cutaneous covering, beginning in the favorite locations and spreading over the entire body, finally resolving by exfoliation. The disease, in these instances, closely resembles dermatitis exfoliativa (see Erythema scarlatiniforme).

The subjective symptoms are mild, and the patient may complain only of slight burning and itching. The systemic symptoms are variable; frequently there will be considerable eruption over the hands and feet, with no general discomfort. Again there may be a marked elevation of temperature, preceded by malaise, headache, rheumatism-like pains, sore throat, and swelling of the joints.

Gastric and intestinal derangements have been noted in the severer cases.

The evolution of the disease is varied. Often erythema will be the only eruption observed throughout the whole attack, while in other cases there will be vesicles or aborted vesicles. Again the lesion may be maculopapular. Sometimes the patch will clear in the center and form opalescent rings. In the more serious cases there may be a diapedesis of blood in the skin. If this is great enough to form distinct purple spots, it is a question if the disease is not purpura rheumatica, and not a true erythema multiforme. It is now almost the universal belief that in its etiology and pathology erythema multiforme is closely allied to the cutaneous lesions of rheumatism. Erythema multiforme is a disease of spring and autumn, although it may occur at other times of the year. Humidity or dampness seems to favor its development. Women, especially young women, are more subject to it than men.

Pathologically it is an angioneurosis, the effect being primarily upon the nerves, secondarily upon the blood-vessels. It is believed by many authorities to be of an infectious nature, although opposing theories appear to be equally well grounded in fact. Cases have been reported of nervous shock followed by an erythematous outbreak.

Microscopical examinations of the lesions show a dilatation of the vessels of the stratum corneum and some exudation of white corpuscles.

Recent observations have not been able to demonstrate the presence of emboli in the cutaneous vessels, although some pathologists claim to have found them.

The *Diagnosis* of the disease is comparatively easy, providing the multiform character and peculiar color of the lesions are borne in mind. The [illegible] lesions upon the hands and feet, and the almost total absence of itching will serve to distinguish it from urticaria.

In papular eczema the papules are smaller and intensely itchy. The course and [illegible] of pemphigus will aid in diagnosing it from the bullous form of erythema.

Erythema nodosum will be known from Erythema multiforme by the presence of bluish nodes on the extremities. The differential diagnosis between Erythema multiforme and Dermatitis herpetiformis is more difficult to make. Careful study, alone, makes differentiation possible. Limited space will allow only a brief outline here. Dermatitis herpetiformis is a chronic disease, and tends to relapse, each recurrence showing the herpetiform character of the lesion; Erythema multiforme is an acute disease, occurring as a rule in the spring and fall, and while in some instances the lesions may be herpetic-like, they always present more or less multiformity.

The *Treatment* of erythema multiforme should be on general lines. At the beginning of the attack a saline purge is indicated; the diet should be light and nutritious; stimulants of all sorts should be avoided; antirheumatic remedies, such as the salicylates, appear to give the best results. In the relapsing cases quinine and iron should be used. Astringent washes, such as lead lotion, will be found useful in treating the skin lesions. If there should be itching a weak solution of carbolic acid or menthol will give relief. Some authors recommend various pastes containing a small quantity of carbolic acid, resorcin, or salicylic acid.

In the beginning of the disease the *Prognosis* as to duration should be very guarded, for relapses may occur that would prolong the attack indefinitely. Generally the disease runs a definite course, lasting from a month to six weeks, treatment seeming to have very little influence upon it.

Erythema nodosum is an inflammatory disease of the skin characterized by various-sized elevated nodes of a rosy red or purplish color.

The disease is generally ushered in with some systemic disturbance; there are malaise, fever, and rheumatic-like pains of the joints.

The nodes begin as dark indurated patches, they appear suddenly and rapidly arrive at full development. Various regions of the body may be involved, although the extensor surfaces of the arms and legs are the parts usually affected. The nodes differ in size from a filbert to a large English walnut. At first they are bright red, gradually growing darker until they become purple, finally fading to a yellowish-blue tint resembling the discoloration of contusions, which has given rise to the synonym erythema contusiforme. Throbbing and pain on pressure are characteristic symptoms; frequently the nodes become so inflamed and shiny that they are mistaken for points of suppuration. The number of the nodes varies; sometimes they are limited to two or three, then again there are four or five times as many. They appear in successive crops, each crop being accompanied by more or less systemic disturbance. Cases have been reported in which there were diarrhea, high temperature, and vomiting.

The *cause* of the disease is not clearly determined, although it is a growing belief that it is due to some acute infection. It is most frequently met with in the anemic and weakly. Exposure to cold in some cases seems to provoke an outbreak. Females appear to be more subject to the disease than males—the proportion being about three to one. It is more frequently seen in early middle life, although I have observed it in people over fifty years of age.

The *pathology* is that of an exudative inflammatory process, similar to erythema multiforme. Some authors claim it to be an inflammation of the lym[illegible]

atics; others, that the nodes are inflammatory infarcts. Many competent observers consider it to be closely allied to purpura rheumatica. The justice of the claim that it is of infectious origin merits more than passing notice; for if the course and symptoms are closely observed it will be found that it bears a marked resemblance to some of the infectious diseases.

There seems to be no doubt that erythema nodosum is in some way closely allied to rheumatism, for the joint and muscular pains are quite similar, and heart involvement has been noticed during a course of the cutaneous disease. It is probable that when the bacteriology of rheumatism is more fully worked out it will be found that erythema nodosum is due to the same or a similar organism.

The microscopical findings are similar to those of erythema multiforme. The capillaries are dilated; there is an infiltration of blood cells into the derma, and the lymphatics are filled with cells. Competent observers have failed to demonstrate free cutaneous hemorrhages in the contused areas.

Diagnosis.—Care must be taken not to mistake the disease for bruises; it is sometimes diagnosed as erysipelas, especially if it occurs about the face. The nodes have been cut into under the impression that they were abscesses. The number and sites of the nodes will help to distinguish it from syphilitic gumma. Giant urticaria differs from erythema in that it is never accompanied by rheumatic-like pains or by fever. The color of the lesions differs, the erythematous nodes are painful, while the wheals of urticaria are itchy. The course of the two diseases is dissimilar; erythema nodosum lasting two or three weeks, while urticaria disappears in a few days.

It might be mistaken for that rare disease Erythema induratum, but this affection runs a slow chronic course, generally terminating in ulcerations.

The distinguishing characteristics of phlebitis, lymphangitis, and erythema multiforme should also be borne in mind.

Treatment.—The treatment is according to the symptoms. If there is much fever antipyretics are indicated. The bowels should be kept open and a simple diet should be prescribed. As regards the general therapeutics, the most reliance should be placed upon salol, salicylate of sodium, quinine, or aspirin; phenacetine, combined with any of the above, aids in relieving the muscular and joint pains. It is well to follow this line of treatment with liberal doses of iron and tonics, especially in weak females. External lotions of lead water and opium relieve the burning pain, or, if preferred, a ten to twenty-five per cent. ichthyol ointment can be used.

The *Prognosis* is favorable; relapses are rare.

Erythema Elevatum Diutinum.—In 1894 Crocker described a disease to which he gave this provisional name. The eruption occurs generally in young anemic subjects, and chiefly affects the hands, lips, knees, and buttocks. The lesions are pale purplish-red in color, and in some cases are sharply defined, in others nodular and irregular in outline. They are firm to the touch and painful when pressed upon. There are few or no subjective symptoms. Cases have been reported in which there was considerable disfigurement from the eruption, the skin being so nodular and infiltrated. The lesions tend to persist, but may undergo gradual involution. Those that do remain become as hard as cartilage. Microscopically there are evidences of inflammatory processes followed by the production of fibrous tissue. It is undoubtedly a mistake to use the term erythema in this disease, for it does not properly apply to the condition, hypertrophic changes being the chief pathological element. The proper classification will be finally decided after further study, but until then it is as well to describe the disease under this caption as elsewhere.

Erythema induratum, or *Erythème induré des scrofuleux*, is a disease first described by Bazin. It is a deep-seated nodular eruption situated in the skin over the legs and fingers.

The nodes vary in size, and are round or oval in shape; as a rule they are few in number, but cases have been reported in which they became confluent. They run an indolent course: some disappear by spontaneous involution, while others suppurate or become necrosed, forming deep circular ulcers. Pain, which may be present, is not severe. Young strumous girls with feeble circulation seem to be especially subject to the disease. It is generally conceded that this is a disease closely connected with tuberculous skin disease—a tuberculide, not a pure tuberculosis.

In diagnosing this disorder erythema nodosum and syphilitic gummata must be thought of. It differs from erythema nodosum in that the lesions are more circumscribed, firmer, and of a darker color; they are more deeply situated in the skin and less tender; they run a chronic course and tend to ulcerate.

Syphilitic gummata are not bilateral, and the patient gives no evidences of other specific symptoms.

Treatment consists of change of air, tonics, and rest in bed.

James Macfarlane Winfield.

Erythema Infectiosum.—*Synonyms;* Fifth disease; Erythema infectiosum morbilliforme; Erythema simplex marginatum; Megalerythema epidemicum.

This condition was first defined as a separate clinical entity in 1896 by Escherich, but was first named "erythema infectiosum" by Stricker in 1899. Some writers have confused this condition with the "fourth disease" or Filatow-Dukes disease. Epidemics of erythema infectiosum have been observed much more frequently in Europe than in America. Ruhräh states that no cases have as yet been observed in America, the disease having been described in Austria and Germany. It is mildly contagious, occurring chiefly in the spring and summer, and characterized by a maculopapular rose-red rash. There are neither complications nor sequelæ. The rash is most pronounced on the cheeks, legs, and outer surface of the arms. The disease appears chiefly between the ages of four and fourteen years. The incubation period is six to fourteen days.

Edmund Cautley in his textbook on "The Diseases of Infants and Children" gives the following description of this disease: "The rash is usually the first sign. It may be preceded by slight malaise, sore throat, and debility. It only affects the skin, and comes out first and characteristically on the face. The cheeks present a symmetrical, confluent, rose-red efflorescence, with defined, slightly raised edges or shading off into normal skin, rather sharply limited by the nasolabial folds and the temples, and extending to the angles of the jaws. The skin is hot and swollen and does not itch. Its color suggests erysipelas and disappears on pressure. Discrete spots are often seen on the forehead, chin, and about the ears. On the second day the rash appears on the body, chiefly the extensor surface of the limbs, and spreads peripherally, the trunk being almost free. On the limbs it is more morbilliform and less rose-red. In many cases it has a lace-work aspect. Above the elbows it becomes confluent. On the buttocks it is marked. It is more macular than papular and shows little elevation except on the face. It disappears from the face in four to five days and from elsewhere in six to twelve days. The color fades from the center first and leaves red irregular rings visible for a time, the skin assuming a 'geographical map,' or 'marbled' aspect (cutis marmorata). Subjective symptoms and complications are rare. Perhaps there is slight fever for twenty-four hours and a furred tongue, but never like that of scarlatina. There is no coryza, cough,

conjunctivitis, glandular enlargement, desquamation, or pigmentation."

In view of the fact that distinct epidemics of this disease, particularly in families and schools, have been described, one cannot subscribe to the view advanced by Stelwagon that the condition is the result of a mild toxemia of gastrointestinal origin. Erythema infectiosum is to be differentiated from erythema exudativum multiforme by the fact that the latter begins on the hands and feet, becomes vesicular, lasts a longer time, and is accompanied by marked constitutional symptoms.

The following table, in which erythema infectiosum is contrasted with measles, German measles, and scarlet fever, is given by Ruhräh in Osler's "Modern Medicine:"

Differential Diagnosis of Rubella, Scarlet Fever, Measles, and Erythema Infectiosum

	Rubella.	Measles.	Scarlet Fever	Erythema infectiosum
Contagion	Apparently varies in epidemics. Direct contact. Possibly from fomites, not through the air.	Highly contagious. By direct contact. By fomites. Through the air.	Marked. By direct contact. By fomites.	Feeble. Usually by direct contact.
Incubation	Variable, average 1 to 3 weeks.	Average 9 to 14 days	Average 1 to 6 days.	Average 6 to 14 days
Prodromes	Slight and of short duration. Occasionally a day or two of malaise.	Three to four days. Drowsiness and catarrhal symptoms.	Short or wanting, onset usually sudden.	Very slight and of short duration.
Koplik spots	None	Present in 90 or 95 per cent. of cases.	None	None.
Vomiting	Rare	Occasional	Common	Uncommon
Fever	Slight, average 1 to 2 days, sometimes for 4 days, seldom more than 101 to 102 degrees.	Marked, high curve, lasting about a week, average from 102 to 105 degrees.	High fever lasting about a week, averages 104 to 105 degrees.	Little or none.
Catarrhal symptoms	Slight	Marked	Absent	None.
Tongue	Slight coat, nothing characteristic.	Tongue coated, that of any fever.	Strawberry, later mulberry tongue.	Sometimes slightly coated.
Throat	Small punctiform red spots over uvula and palate. Pharynx slightly reddened.	Moderate pharyngitis and redness of mucous membranes.	Usually a severe angina	Sometimes very slight sore throat at onset.
Diarrhea		Frequent		
Lymph-nodes	General enlargement, especially of postcervical nodes.	Postcervical, postauricular, and submaxillary nodes enlarged.	Depends on extent of throat involvement, glands at angle of jaw involved.	Not enlarged.
Pulse	Varies with fever	Varies with fever	Very rapid	Normal.
Albuminuria	Rare and slight	Rare	Common	None.
Eruption	Begins on face, spreads to neck and breast, then to arms, legs, and feet. Is fading from other parts while spreading to new. Two forms: common form, morbilliform, small slightly elevated papules, discrete, sometimes confluent, more rarely scarlatiniform. Lasts 2 to 4 days or less, color rose-red, but this varies.	Begins on face, spreads gradually over entire body—covering it by the second or third day. Consists of small papules arranged in crescentic groups; these are confluent in places. Lasts 4 to 5 days. Is deep red, often purplish.	Begins on neck and chest, spreads slowly over entire body—maximum about the fourth day. Does not affect lips. Consists of small punctate spots, or a diffuse blush; disappears on pressure. Lasts about a week. Intense red color.	First on face, as symmetrical rose-red blush, for the most part sharply defined, and resembling erysipelas. It is hot to the touch, but is not sensitive and does not itch. The second day it spreads to the body and extremities, small discrete crescentic patches over the body and spreading to the inner and flexor surfaces of limbs. Marked map-like eruption on outer and extensor surfaces. Begins to fade on face in 4 or 5 days. Lasts altogether 6 to 10 days.
Desquamation	Slight and branny	Branny	Marked in flakes and large pieces.	None.
Convalescence	Rapid, no complications.	Slow, frequent complications, as pneumonia; later other infectious diseases, as tuberculosis.	Slow, complications frequent, as nephritis, otitis media, etc.	Rapid, no complications.

Alexander Spingarn.

Erythrasma.—This is a cutaneous *disorder* rather than a *disease* of the skin strictly speaking, and is due to the presence and growth, *on* and *in* the superficial layers of the epidermis, of a vegetable parasite. The affection was first described by Burchardt in 1859 and by von Barensprung in 1862, who thus named it. Later it was studied by Besnier, Balzer, Dubreuilh, Riehl, Crocker, and many others who all agree that it is a distinct affection. It is an extremely rare though trivial affection; it produces no inconvenience and is usually only accidentally discovered. During the past eighteen years no instance of it has been noted in the dermatological department of the Vanderbilt Clinic, New York City, where the examinations, at least among the male patients, in whom it is said to be most common, is of the most open kind. The parts attacked are primarily those situations of the body—such as the axillæ, the inguinal and genitocrural regions, and the cleft of the nates—where, the apposed surfaces of the skin coming in contact, warmth and moisture are most constant. To these situations the parasite may confine itself indefinitely, but sooner or later if uninterrupted in its course) the growth spreads slowly to contiguous

parts and the trunk and limbs become invaded. These parts, however, may be attacked independently. The affection first manifests itself in the form of macules of the size of a pinhead or in patches of a somewhat larger area, the lesions varying in color according to their age and location, but always presenting a sharp contrast to the color of the adjacent normal integument. The younger lesions are vividly red over their entire surface or at their borders only, where a slight elevation above the general surface, due to hyperemia and to the presence of a scanty desquamation, may be detected by the passing finger. The larger and older patches display varying shades of color ranging from a yellowish or light brownish tinge to deep orange, they are circular or rosette-shaped or they have very irregular outlines. Vesiculation and papulation never occur and the only subjective symptom is possibly that of itching. It is the most chronic in its course of the dermatomycoses and lasts for months or years with but little change. Males are more frequently attacked than females; no case has been noted in childhood. Riehl's youngest case was sixteen years old, the oldest fifty-eight.

The fungus to which erythrasma is due was named by von Bärensprung *Microsporon minutissimum*, the chief characteristics of which are the fineness of its threads and the minuteness of its spores. A power of six hundred diameters is required to make out the organism well. The threads present an inextricably interwoven mass with the spores scattered throughout in irregular clumps.

Erythrasma is chiefly to be distinguished from chromophytosis, but the different situations usually occupied by the former, its vivid coloring, and particularly the differences observed under the microscope are features sufficiently distinctive to enable one to make a positive diagnosis when in presence of one or the other affection. From chloasma, for which it might possibly be mistaken, it may be shown to differ by the ease with which erasion removes the superficial discolored epidermis.

The following simple plan of treatment will be found all-sufficient. After a preliminary hot bath, during which vigorous friction of the affected parts with scrubbing brush and soap has been maintained, a goodly proportion of the invaded epithelium will be found to have been removed, thus allowing a saturated solution of hyposulphite of sodium in water to do its work effectively. Afterward this solution should be dabbed on twice daily until the last trace of the parasite has been removed, for, as in chromophytosis, if this be neglected, even to the extent of overlooking so small a lesion as a pinpoint-sized macule, a starting-point will be left for reinvasion. Many other remedies are used. The list includes, sulphurous acid pure or dilute, a good remedy; a ten-per-cent. ammoniated mercury ointment; and ordinary sulphur ointment of the Pharmacopeia, to be well rubbed in. None of these, however, can be compared as regards both cleanliness and effectiveness, with the hyposulphite of sodium treatment.

Charles Townshend Dade.

Erythremia.—Polycythemia (Erythremia) with chronic cyanosis and enlarged spleen came first under clinical observation in 1892, when Vaquez[1] published the report of a case in which he attributed these phenomena to congenital heart disease. Autopsy upon this case in 1895[2] showed the heart to be normal. In the same year (March 27, 1892) Rendu and Widal[3] had under observation a case (not reported till 1899) with the above symptom-complex which they attributed to tuberculosis of the spleen. This case, as appears by the title of their article, they reported as one of primary tuberculous splenomegaly ("Splénomegalie tuberculeuse primitive") in 1899[3] but at the autopsy (Sept. 17, 1904) general visceral tuberculosis was found. The spleen contained large caseous areas and weighed 4,000 grams. The heart was normal. Vaquez's patient had died of acute tuberculosis. It was difficult at that time not to associate tuberculosis in some form with the clinical phenomena presented by these cases, an association amply disproven by many cases now on record. It is perhaps this association with tuberculosis, emphasized by Rendu and Widal, that leads one to feel that Vaquez) rather than Rendu and Widal, was the first to suspect this symptom-complex of being a *clinical entity* though he, too, mistakenly attributed it to congenital heart disease until 1895 when the autopsy on his case showed him to be in error. At the time that Rendu and Widal's report appeared (1899) Cabot[4] in Boston reported a case "without discoverable cause." It may be interesting to mention here an article by Cuffer and Sollier[5] on congestive venous diathesis (diathèse congestive et congestion généralisée) published in 1889 prior to any of the above, but these authors do not seem to have recognized a clinical entity. Moutard-Martin and Lefas[6] also attributed the clinical phenomena to tuberculosis of the spleen (1899) and so designated the condition in the title of their article. Cabot's[4] report (1899) of a case "without discoverable cause," Cominottis 1900[7] "Hyperglobulie und Splenomegalie," McKeen's[8] (1901) case in which the phenomena were "difficult to ,explain" and Saundby and Russel's[9] report of "an unexplained condition" which they designated as "a definite clinical entity . . . new to Medical Science" brought the disease conspicuously to the attention of clinicians in various countries, and from 1903 reports of several cases appeared annually in the literature. Up to 1903 about twelve observers had reported upon the condition. In 1903 there appeared six reports conspicuous among which was that of Osler[10] under the title ". . . A New Clinical Entity" which brought the subject to the attention of American clinicians and went far to systematize the features of the disease as observed up to that date. Following this report the condition came to be spoken of as "Osler's disease" though it is now more generally known as "Erythremia," "Primary Polycythemia" or "Vaquez Disease." It has also been termed "Myelopathic Polycythemia," "Splenomegalic Polycythemia," "Erythrocytosis Megalosplenica," Polycythemia Vera," "Cryptogenic Polycythemia." Erythremia is the term now most in use. Of the eponymic terms "Vaquez" and "Osler" are those most commonly used. From 1903 the cases appear in literature in increasing numbers until now (1914) there are about 200 on record. Lucas[11] in 1912 brought the literature up to date in a carefully tabulated list of cases.

Symptoms.—The patients complain of headache, vertigo, a sense of fullness in the head, the dark color of the skin and lips, lassitude and weakness. To these may be added the results of congestion in other parts of the body, cough—with or without expectoration—dyspnea, asthmatic seizures, palpitation, swelling of the legs and feet, and hemorrhages. The gums and nose are the commonest seat of hemorrhage. Skin hemorrhages (petechiæ and purpura) are not recorded. Disturbance of vision—described as blurring—may be complained of. There may be very marked loss of vision. Diplopia occurs. The eye symptoms may be an important factor in some cases. According to statistics gathered by Lucas, eighty-three per cent. of the cases complained of the dark color of the skin and lips. This outranks considerably all the other symptoms referred to by the patient. Vertigo (34.5 per cent.) and headache (31 per cent.) or pain in some part of the body come next. Constipation, diarrhea, anorexia, vomiting, loss of weight, sweating, tinnitus aurium, disturbed menses occur, but these are so common in many other conditions that they will hardly serve as a guide in diagnosis. Cyanosis and

results of cerebral congestion are the most frequent and most important symptoms referred to by the patient.

Symptoms referable to the nervous system are many and varied. The majority of them suggest the disturbances found in the psychoses. Insomnia, hypochondriasis, irritability, apprehension, etc.; also aphasia, tremors, "globus" fainting, swooning without loss of consciousness are recorded. Paralyses and epileptiform attacks are also mentioned. There is no evidence given to show that these latter are the result of organic brain lesions, except where pressure from cerebral congestion or hemorrhage has occurred.

Signs.—*The Skin and Mucous Membrane.*—By far the most striking of these is the cyanosis. The patient appears in marked contrast to those about him. The face looks either suffused or dusky; the lips and tongue being somewhat darker, while the ears and nose show a tint different from either that of the face or mucous membrane. The nose may be venuled. Mental or physical effort and change in surrounding temperature may change the intensity of the color so that the color may be red at one time and deep indigo at another. Cold seems to intensify the bluish tint while warmth intensifies the red color. The hands and feet also show discoloration and the nails may be curved or there may be incurvation of the nails, together with clubbing of the fingers. Compared with the individual's own face and hands the skin of the body does not seem abnormal in tint. If, however, the body skin be compared with that of a normal individual, the bluish-red color will appear in striking contrast. Thus it is seen that, while the cyanosis is general, it is more marked in the face and hands. The vessels of the facial and pharyngeal mucous membrane and the conjunctivæ may be injected due to engorgement by red cells. There are other less important and less constant skin symptoms referred to by some authors such as dermatographia, erythromelalgia, tache cérébrale, etc.

The Eyes.—In addition to the changes in the conjunctivæ above referred to there may be some important organic changes. All cases should be thoroughly examined with the opthalmoscope. Such an examination may reveal engorged, tortuous, dark colored veins. These changes are not always symmetrical. There may be edema with blurring of the discs. In a few cases double optic neuritis is reported. Choked disc is rare. Edema would appear to be the most likely condition occurring in these cases. Oculists have made several valuable contributions regarding the eyes in this condition[12] [13] [14]. Exophthalmos is rare.

Thoracic viscera are normal. The cases on record practically establish the fact that this condition has nothing to do with either congenital or acquired heart lesions—the condition, moreover, seems to have no tendency to produce lesions in the heart. The palpitation, dyspnea, cough and asthma complained of are results of the vascular engorgement and not due to cardiac or pulmonary lesions, except when such lesions are complications of the erythremia.

Abdominal Viscera.—The liver is usually not enlarged. Slight enlargement is reported in a few cases. There is no characteristic change in this organ. The stomach and intestines present no signs but such symptoms only as have already been referred to. The spleen is enlarged and this enlargement constitutes one of the characteristic features of the disease. A few cases are reported in which no enlargement was found (eight per cent.) The degree of enlargement may be from "palpable" to "reaching below the iliac crest." While there may be symptoms referable (see Symptoms) to other abdominal viscera, there are no signs to indicate that such viscera are the seat of pathological change. Possibly congestion would account for the subjective symptoms complained of.

Nervous System.—While there are many symptoms suggestive of involvement of the nervous system (hemiplegia, diminished knee-jerks, aphasia, etc.) reported, these seem to have no constant association with the disease, and it would appear from the reports on record that the nervous system is not structurally involved. Functional phenomena, due to the abnormal state of the circulation, are common.

The Blood.—The changes found here constitute one of the three features upon which the disease has been accepted as a clinical entity. Cyanosis and splenic enlargement may, either one or the other, be absent and yet the diagnosis of erythremia will be justified, but polycythemia is an essential feature in what is now known as erythremia. Directly the mechanical causes for red cell excess (such as congenital heart lesions, venous obstruction, etc., see Etiology), are excluded, the condition must be studied with relation to the blood-making organs as is done in considering the anemias and leukemias. It is thus that the term "Myelopathic Polycythemia" got into literature. The peripheral blood in this condition then should be studied as an expression of the efficiency or inefficiency of the blood-making apparatus. Grossly the blood when drawn looks dark, thick, and is described as "sticky." The *absolute increase* in the number of red cells is always present. The degree of increase varies in different individuals and in the same individual at different times, but there is at all times an excess of red cells. The lowest counts on record are between six and seven million red cells and the highest (two cases) were fifteen million red cells or a little over. Most of the cases fall between six and eleven million red cells. The hemoglobin is low in most cases; that is, in relation to the number of red cells. On the scale it is actually high and sometimes cannot be estimated as it exceeds the figures found on the scale of most instruments. The Von Fleischl scale does not extend beyond 120° and many reports give this figure as the percentage. The blood should be further diluted (one-half for example) in determining the hemoglobin in erythremia. One accepts with reservation the reports on the hemoglobin percentage in many of the cases. Some observers give two estimates as 120°–160° (Snyder), 150°–240° (Kuttner), 130°–145° (Ronaldson) and it will be observed that these are usually in percentages above 120°. The probability is that the hemoglobin in all counts above ten million red cells is much higher than reported. The color-index likewise is probably underestimated. It is probably nearer normal in most instances than the reports show—certainly not high. The volume index is not reported upon.

The white blood-cell count shows a slight polynuclear leucocytosis; in a few instances a definite leucocytosis. The stained specimen in a few of the reported cases shows slight polychromatophilia, but this is not usually associated with changes in the size and shape (anisocytosis) of the red cells. These latter findings are important in the question as to whether a regenerative or degenerative process in the blood-making structures is responsible for the great increase in red cells. A red-cell hyperplasia or overproduction would be in accord with this finding of *well formed* cells in the peripheral circulation. Nucleated red cells are reported in a few cases. The white cells show a polynuclear increase in most cases. A few cases show a lymphocytic and eosinophilic increase. Myelocytes are reported in 8 cases.

To sum up the findings in the stained specimen it may be said that the blood appears to be differentially and morphologically normal except for a slight polynuclear increase, and occasional changes in the uniformity of the staining and in the size and shape of the red cells, and in the occasional occurrence of abnormal cells. Coagulation time is increased. Viscosity is usually raised. Other abnormal features of the blood have been observed in too few cases to warrant our drawing reliable conclusions from them, or in stating them as features of the blood in this disease.

Pathology.—About twelve per cent. of the recorded cases have come to autopsy. The autopsy records in these are very incomplete, so that out of the twenty-five or thirty records only about ten or twelve are available for the systematic study of the viscera. In only fourteen or fifteen of these was the bone marrow examined and in only three or four was a thorough study of the marrow made. Such statements as "Marrow of long bones red," "Hyperplasia of red cells" in many instances comprise the information given regarding the bone marrow. When, however, the pathological findings from all the autopsy records are put together we obtain the following:

Bone Marrow.—In the bone marrow of the long bones there is loss or entire disappearance of fat cells. The fat cells are replaced by dark "bluish-red" areas of erythroblastic activity. These two findings constitute by far the commonest pathological changes recorded. An increase of all cellular elements of the bone marrow with an increase of the nucleated red cells and an enormous increase in the total number of nucleated red cells appears in several reports. One report gives the leucoblastic tissue in excess of the erythroblastic. The most constant finding is the replacement of fat cells by normoblasts and giant cells, with the consequent gross appearance of red marrow in the long bones. Mast cells are seldom reported as present. Cellular proliferation is commonly recorded. In one case the marrow is reported as normal.

The Spleen.—In the majority of cases the spleen was enlarged—1,800 grams, 1,500 grams, 1,000 grams being the figures given—one case (Rendu and Widal) is recorded as 4,000 grams. A few cases are given as "small" or "not enlarged." Infarcts or anemic infarcts, and fibrosis or fibrous bands are frequently recorded. Perisplenitis or adhesion is mentioned in a number of the autopsy records. Scattered yellowish patches or nodules, which some authors infer are tuberculous, are mentioned in several reports. Other authors definitely state that these patches and nodules are not tuberculous. "Myeloid transformation," "erythroblastic and leucoblastic blood formations," "excess of eosinophiles," are expressions appearing in Lucas' résumé of the autopsy findings. We find also the spleen spoken of as engorged with only remnants of malpighian tissue. From these records it is difficult to draw conclusions. That tuberculosis is not the lesion found in the spleen is definitely proven. The frequency with which the formation of fibrous tissue in and about the spleen is reported is to be noted. Under etiology will be discussed the possibility of a toxic agent acting, as in anemia, in the erythroblastic activity.

The Liver.—This organ is usually enlarged but not greatly so. The records are inconstant. Adhesions, however, between the liver and spleen and between the liver and other viscera are mentioned quite frequently.

The Heart.—In a few instances myocardial and valvular lesions were found. In no instance was a congenital valve lesion found—most records state that the heart was "normal."

Other viscera are mentioned in the autopsy records but the lesions were in most instances due to other diseases or had no apparent connection with erythremia. Thus emphysema, pulmonary tuberculosis, pulmonary congestion, visceral congestion, cerebral hemorrhage, nephritis, etc., appear on the records. Hemorrhage is perhaps a feature to be remembered. The skin and mucous membrane hemorrhages, however, are not recorded.

Etiology.—The etiology is unknown. Three fea, tures mark the disease under consideration: cyanosis-polyglobulism, enlarged spleen.

The condition indicated in all cases of cyanosis, whether local or general, is "diminished oxidation of the blood corpuscles" (Osler), and again "there are two classes of polyglobulism—*relative*, in which the condition is due to a diminution in the quantity of the plasma of the blood, and *true*, in which there is an actual increase in the number of blood corpuscles" (Osler). The first of these is common and may be caused by ingestion of too little fluid or excessive loss of fluid as in sweating, diarrhea, diuresis, ascites, excessive secretion (pyloric narrowing with gastric dilatation), etc.

Polyglobulism may also be caused by exercise, cold baths (vasomotor disturbance) emphysema, pulmonary fibrosis, congenital heart lesions, myocardial, pericardial, and tricuspid disease and thromboses, poisoning by coal-tar products, by carbon monoxide, and phosphorous. Probably atmospheric pressure at high altitudes may also be included in this list.

In considering true polycythemia (polycythemia vera) all these causes must be excluded. That of atmospheric pressure is perhaps in some way akin to true polycythemia but this is by no means clear.

The third feature of this disease, splenic enlargement, is suggestive of a toxic agent. In pernicious anemia, we have experimental evidence suggesting such a cause. (See *Anemia, Pernicious; (Addisonian)*; Etiology: Reference Handbook, vol. i., p. 347.) It is conceivable that one toxic agent may act upon the blood-forming apparatus in such a way as to destroy red cells and stimulate production (anemia), and another in such a way as to stimulate production without correspondingly great destruction of the red cells (erythremia). The splenic enlargement, the tendencies to the formation of adhesions between the viscera, the enlargement, with occasional cirrhosis, of the liver, together with other clinical and postmortem findings, lead one's mind to the thought of a toxic agent as the primary factor. There is only one experimental effort to prove Metchnikoff's (Lucas')

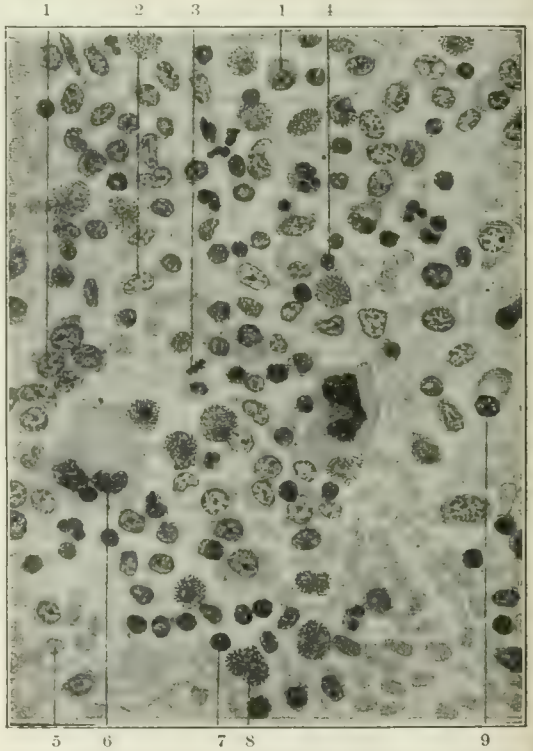

Fig. 2095.—Bone Marrow of the Shaft of the Femur in Erythremia. 1, 1, Basophile myelocytes; 2, myeloblast of Naegeli; 3, myelocyte in process of mitosis; 4, normoblast; 5, erythrocyte; 6, megacaryocyte; 7, lymphocyte; 8, cosinophile myelocyte; 9, plasma-cell (After Chauttard and Troissier.)

theory of a hemolytic toxin of splenic origin. This theory suggests that the toxin has a marked stimulating effect upon the blood-making organs but very feeble in its hemolysing power. Such a serum (hemolytic) was injected into patients with anemia by Belonovsky (1902) with the result that both the red cells and hemoglobin were increased.

Chauffard and Troisier[15] report upon a case of polycythemia associated with phlebitis of the splenic vein and thrombosis of the gastric epiploque vein. The case is discussed as if in the group of erythremias and accompanying their article is an illustration showing extensive varicosity of the abdominal and chest veins. There is, however, in this report an illustration (Fig. 2095) of the marrow of the femur as seen under the microscope and in this the normoblasts are numerous. In this connection Chauffard and Troisier's article will bear careful study. The red cells numbered 9,500,000. The spleen showed at autopsy dense bands of adhesion (Fig. 2096) and weighed 367 grams. It is possible that a toxic agent was responsible, as the primary factor, in the production of the phlebitis, thrombosis, and polycythemia. The case would thus be one

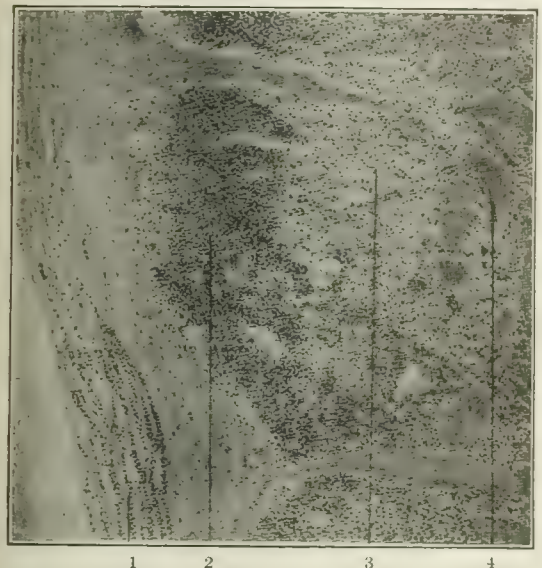

Fig. 2096.—The Spleen in Erythremia. 1, Perisplenitis with newly formed capillaries distended with blood cells; 2, zone of intense congestion; 3, zone of sclerosis of the pulp; 4, fibrous bands. (After Chauttard and Troissier.)

of erythremia primarily, complicated by phlebitis and thrombosis of the veins above mentioned. The toxic agent responsible for the phlebitis and thrombosis would also be responsible for the erythroblastic activity. The experimental evidence to support this view is, however, very meager, and while it is the most acceptable explanation it must be taken as yet upon a theoretical basis.

Diagnosis.—The clinician is referred to the discussion under etiology where a list of causes producing polyglobulism will be found. It is rarely difficult to exclude the causes given in this long list, as each offers distinctive features. The one constant feature of erythremia is the absolute and persistent polycythemia. Cyanosis and splenic enlargement may one or the other or both be absent and yet the diagnosis of erythremia be justified, provided all the known causes of polyglobulism have been excluded. Though in some of the cases of known cause (congenital heart and chronic lung and heart disease—atmospheric pressure of high altitudes) there has been shown to be erythroblastic overactivity (erythrocytosis) in the bone marrow, this does not admit such cases into the erythremia group. Erythrocytosis must be differentiated from erythremia. This has the support of experimental proof and the most distinctive feature by which the blood of erythremia can be detected is that the increase of red cells is *absolute* and *persistent*. Add to this the vertigo, [illegible] and eye ground findings and the diagnosis is established.

Prognosis.—The disease is almost uniformly fatal. Ten to fifteen years is the longest period of survival, according to Lucas's figures.

Treatment.—No effectual treatment is recorded. Splenectomy is followed by death in a few days in the cases reported. *X*-ray, faradization, and a long list of drugs, including arsenic, show little in their favor. Sodium nitrite and sodium bromide and venesection yield marked temporary relief. C. N. B. Camac.

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Erythroderma Squamosum.—See *Parapsoriasis*.

Erythrol Tetranitrate.—Erythrol is a tetratomic alcohol, and is a decomposition product of erythrin. Erythrol tetranitrate is also known as tetranitrin and nitro-erythrite, and occurs in the form of hard white crystals. It must be kept in a cool, dark place, as it is decomposed by light and heat; and, since it explodes on percussion, it must be handled with care. It is soluble in boiling water, alcohol, or ether, but is insoluble in cold water.

CH_2OH	CH_2ONO_2
CHOH	$CHONO_2$
CHOH	$CHONO_2$
CH_2OH	CH_2ONO_2
Erythrol	Erythrol tetranitrate.

As will be seen from its constitution, erythrol tetranitrate is a nitrite and, like amyl nitrite and nitroglycerin, it is a vasodilator; but its action is slower, less powerful, and more prolonged. It is useful in cases of chronic nephritis, asthma, aneurysm, and angina pectoris. The ordinary dose is gr. ½–1 (0.03–0.06), but it can be increased with safety up to three grains or more. It is best administered in the form of tablets. R. J. E. Scott.

Erythromelalgia.—Under the name of erythromelalgia (ἐρυθρος, red; μέλος, a limb; ἄλγος, pain), Weir Mitchell, in 1873, described an affection, characterized by redness and pain of the extremities, which he defined as "A chronic disease in which a part or parts of the body, usually one or more of the extremities, suffer with pain, flushing, and local fever, made far worse if the parts hang down." Cassirer collected reports of some ninety cases in which these symptoms were present, but concluded that probably the majority were not true examples of erythromelalgia. All depends upon what one has in mind when he uses this name. According to Osler it should be limited to

those cases in which neither vascular disease nor disease of the central or peripheral nervous system is present to account for the symptoms, and while he has observed quite a number of cases in which there were redness, swelling, and pain of the extremities, he can recall only one case, seen in private practice, which he felt able to consider a true example of the affection described by Weir Mitchell. It is undoubtedly a rare disease even if all the cases which show the above-mentioned symptoms are classed as erythromelalgia.

Etiology.—As causative factors a number of things have been mentioned, the association in most instances being probably accidental. A few cases seem to have followed infections of some kind, in some, long exposure of the extremities to cold or wet seems to have played a rôle. One case seen recently seemed to be connected with chronic alcoholism, but in this there was suspicion of a slight neuritis. It is not limited to any age though most frequent in adult life and affecting men more often than women.

Pathology.—Erythromelalgia involves the extremities, one or both, most usually the feet, never the nose or ears. Cassirer finds that it can be divided into two classes of cases: (1) Those in which the redness and pain are localized in the territory of a definite nerve or nerves; (2) cases affecting the distal part of a limb. In the first, a neuritis might reasonably be suspected, while in the second, the change might be located in the central nervous system. The findings, however, have been variable; in some cases there has been slight neuritis, in others equally characteristic, none. Lesions of the posterior roots have been observed and in other cases changes in the arteries of the affected part, though, according to Osler, cases showing the latter change should not be included under erythromelalgia. He suggests that a cervical rib may be a cause of the symptoms in some cases.

Symptoms.—The characteristic symptoms are redness, varying from bright pink to a deep livid color, coming on particularly when the limb hangs down, and disappearing wholly or in part with rest in bed. This is accompanied by pain usually of a throbbing or burning character, though it may be a dull ache, or may shoot through the part from time to time. There is usually hyperesthesia, stroking the part being very painful. This pain may be greatly relieved when the part is kept up and quiet, and the patient may have pretty comfortable nights, though on the other hand it may persist. With the above symptoms there is generally swelling of the part, and there may be local rise of temperature and sweating, while vesicles may form. In some cases there has been slight atrophy of the muscles and local hypesthesia or anesthesia.

Diagnosis.—Red painful neuralgia has been found associated with definite disease of the spinal cord, with multiple sclerosis, with neuritis, with Raynaud's disease, and with endarteritis obliterans. Each of these possible underlying conditions should be eliminated before a definite diagnosis of erythromelalgia is made. As distinguishing between Raynaud's disease and erythromelalgia, Weir Mitchell gives the following diagnostic table:

Raynaud's Disease.	Erythromelalgia.
1. Sex, four-fifths females.	1. In twenty-two cases, two women only.
2. Begins with ischemia	2. Little or no difference in color until the foot hangs down, or in the upright position, when it becomes rose red.
3. Part bloodless, white, some cases show deep dusky congestion, with or without gangrene.	3. Arteries throb, color pink to dusky red or violaceous.
4. Pain absent or acute, comes and goes, has no relation to posture, may precede asphyxia.	4. Pain usually present, worse when the limb hangs down or is pressed upon; in bad cases more or less all the time.
5. Unaffected by season, may have symptoms brought on by cold.	5. Worse in summer, made worse by heat, eased by cold.
6. Anesthesia to touch.	6. All forms of sensation preserved.
7. Analgesia.	7. Hyperalgesia.
8. Temperature lowered, unaltered by position.	8. Temperature above normal; dependency of limb causes in some cases increase, in others lowering of temperature.
9. Gangrene local, limited, usually symmetrical.	9. No gangrene, lesion asymmetrical.

Prognosis.—This should be guarded, as many cases last for an indefinite period, little modified by treatment. In others, however, cure takes place spontaneously as in the case described by Osler.

Treatment is unfortunately of little avail in many instances. Most cases are relieved by keeping the feet up, best by rest in bed. The various analgesic ointments with ichthyol, menthol, etc., may be applied, and as a rule cold applications are more agreeable than warm or hot ones. Electricity, with mild galvanism, the positive pole to the affected part, or the high frequency current may be tried.

It has been suggested that Bier's hyperemic method as modified by Cushing might be of advantage, but to many of the patients it is very painful. Moleen has recently reported a case of fourteen years' standing which was greatly benefited by long-continued administration of small doses of tablets of suprarenal body.

Alcohol and tobacco had best be avoided, and while the pain at times may be so intense as to demand them, it need hardly be urged that in so chronic an affection, the opium preparations had best be held as far as possible in the background.

In each case search should be made for some cause of obstruction to the return circulation in the limb, and if found it should be removed, if possible.

In cases limited to the territory of a definite nerve, it has been proposed to excise a portion of this nerve.

Charles Lewis Allen.

Erythrophleum.—Sassy Bark, Mancona Bark.—The bark of *Erythrophleum guineense* Don. (Fam. *Leguminosæ*), a good-sized, acacia-like tree, growing in tropical Africa, and employed by the tribes of the west coast like Calabar beans, as an ordeal. It is a ponderous bark, heavier than water, of a dull red color, a fissured external surface, and a short fracture. Odor slight, taste astringent. The active principle of sassy bark is *erythrophleine*, a crystalline alkaloid, first obtained by Gallois and Hardy. It is an active heart-poison of the digitalis kind, producing slowing of the pulse, increase of blood pressure, and in experiments upon animals death, with the heart in systolic contraction. The powdered drug is a powerful sternutatory. But little use has been found for this potent medicine. It is sometimes used like digitalis, in doses of one to three grains, of the bark, in the form of a tincture, but is far less certain and regular and even more inclined to upset the stomach. It is said to be employed at home in dysentery, etc., with benefit, as well as in intermittent and other fevers. In full doses it is nauseating and emetic, as well as somewhat narcotic.

W. P. Bolles.

Erythroxylon.—See *Coca*.

Eschetocephalus.—A genus of ticks, *Ixodinæ;* without eyes and with a long rostrum. The seven species are found on bats and in caves. See *Arachnida*.

A. S. P.

Eschscholtzia.—A genus (fam. *Papaveraceæ*) of ten or more species, of the western and southwestern United States and of countries lying farther southward. Medicinal properties have been credited to the

E. californica Cham., but this was at a time when most of the species were included under that name, so it is not now known certainly to which species (one or more) these properties were said to belong. The plants are very showy and are widely cultivated for ornamental purposes. The herb contains chelerythrine (see *Celandine*) and at least one other alkaloid, and a glucoside. The presence of a small amount of morphine has been claimed, but this is probably not justified. Mild analgesic and soporific effects are obtained from the use of the extract in doses of about one gram, which may be increased to three or four times this amount. HENRY H. RUSBY.

Eserine.—See *Physostigmine.*

von Esmarch, Johann Friedrich.—Born in Tönning, Germany, on January 9, 1823. He pursued his medical studies at the universities of Kiel and Goettingen, and received the degree of Doctor of Medicine in 1848. In 1849 he settled in Kiel, and held there successively the following official positions in the University: Privatdozent, in 1849; Director of the Surgical Clinic, in 1854; and full Professor of Surgery and Director of the Hospital, from 1857 to 1899, when he voluntarily resigned these positions and was honored with the title of "Geheimer Ober-Medizinal Rath." In 1870 he was made Surgeon-General

FIG. 2097.—Johann Friedrich von Esmarch.

of the Germany Army. His two most important contributions to medical science are the following: "Ueber künstliche Blutleere bei Operationen" (artificial production of bloodlessness for operative purposes), in Volkmann's Sammlung klinische. Vorträge No. 58, 1873; and "Samariter-briefe," 1886. (It was Esmarch who established the first "Samaritan Schools" in Germany, in imitation of the St. John's Ambulance Classes organized in England in 1878.) He also published two other books of prime importance, viz., "Handbuch der kreigschirurgischen Technik," 4th edition, 1894; and "Die erste Hilfe bei plötzlichen Unglückfällen," 10th edition, 1892. Esmarch died at Kiel on February 23, 1908. A. H. B.

Esophagoscopy and Gastroscopy.—HISTORY.—The first recorded attempt at esophagoscopy was the examination of the upper end of the esophagus by Bozzini in 1807. Voltolini and Waldenberg, in 1860, and Stoerck, in 1861, used specula illuminated with the laryngeal mirror. These early attempts were limited to the examination of the upper end of the esophagus. The first esophagoscopy of the thoracic esophagus was done by Kussmaul in 1868. He used a straight and rigid tube passed with the patient in the "sword swallowing" position. He did not pass the cardia but he made a diagnosis of carcinoma of the thoracic esophagus. Trouvé, in 1873, designed a "polyscope" fitted with an optical apparatus which Ledentu and Rey used to [illegible] cial stricture of the esophagus near the cardia. Collin with the same instrument, demonstrated endoscopically the functions of the stomach of a bull. Mikuliez, in 1881, designed an esophagoscope on the principle of the Leiter cystoscope using an optical apparatus which gave an endoscopic view through a lateral window. He added an angle and an extension to his esophagoscope and with this gastroscope examined the human stomach. In 1891, Gottstein still further developed the esophagoscope and [illegible] under cocaine anesthesia, all former esophagoscopy having been done under either general anesthesia or morphine narcosis. Rosenheim, in 1896, devised a gastroscope using a very much improved lens system. In 1899, Killian established esophagoscopy as a practical procedure. Einhorn, in 1902, devised an esophagoscope illuminated by a minute lamp at the distal end of the tube, being held there by means of a light carrier which was passed through an auxiliary tube made in the wall of the esophagoscope. This not only gave a brilliant illumination at the point most needed but it also permitted of withdrawal of the lamp for adjustment or renewal without removal of the esophagoscope. In 1904, Chevalier Jackson combined the lighting principle of the Einhorn esophagoscope with the tube of Killian and placed in the esophagoscope an auxiliary canal for the drainage of secretion by aspiration. By elongating this instrument he developed a gastroscope and demonstrated that for safety a gastroscope should be passed by sight with the open tube. In 1906, Bruennings devised a system of proximal illumination with a telescopic tube. In 1909, Kahler developed a panelectroscope for all forms of peroral endoscopy. In 1912, Henry Janeway modified the open tube of Chevalier Jackson and designed for use through it a practical lens system which permitted of the examination of the interior of the stomach when inflated.

DEFINITION.—Esophagoscopy is a procedure using a tube which serves as a speculum, by drawing aside anatomical structures which normally obstruct the view, or by dragging the tissues to be examined into a new position in the line of vision. Gastroscopy may be similarly defined with this in addition, that after the specular tube is introduced a lens system ending in a prism at its distal end may be inserted and an indirect image of the interior of the air-inflated stomach may be thus obtained.

INDICATIONS FOR ESOPHAGOSCOPY.—Until the development of esophagoscopy but little was known of esophageal disease, diagnosis was late and uncertain, and treatment was not only hopeless, but dangerous. Esophagoscopy has given all the certainty and safety of ocular inspection to the diagnosis and treatment of esophageal disease. Specimens are removed for the diagnosis of ulcerative and neoplastic conditions. Foreign bodies are removed quickly and safely and local, medical or surgical measures are used with results which compare favorably with those of similar diseases elsewhere. Esophagoscopy is indicated in any case with regurgitation, with any abnormal sensation in swallowing, with any abnormal sensation in the gullet such as so-called "globus hystericus"; and also in any case in which there is reason to suspect the presence of a foreign body in the esophagus.

CONTRAINDICATIONS.—There is no contraindication to esophagoscopy for the removal of foreign bodies unless the patient is moribund from esophageal trauma from ill-advised blind efforts at removal; a state which, while less common than formerly, is still not unknown. If the patient is in bad condition from this cause, it is better to give stimulants, elevate the foot of the bed, keep the patient warm with blankets and hot water bottles and to use all other means to

counteract the shock of acute traumatic esophagitis before removing the foreign body. Bismuth taken dry on the tongue is the best local treatment in these cases. If there is a serious state of water hunger from occlusion of the esophagus by disease, it is wise to have the general surgeon do a gastrostomy and to supply fluid food for a few days before doing the esophagoscopy, rather than wait for the esophagoscopic diagnosis; because water-starvation is an exceedingly dangerous state, and, moreover, outside of foreign bodies there is no stenotic condition in the esophagus that is so quickly relievable by esophagoscopy that the gastrostomy would not be necessary anyway. Aneurysm, serious cardiac diseases, history of apoplexy and the like are not contraindications for the esophagoscopic removal of foreign bodies, but they render esophagoscopy for any other purpose inadvisable. Every case of esophageal trouble should have aneurysm carefully excluded before esophagoscopy; so that if present, extreme caution to avoid vomiturition and vomiting can be exercised. In acute esophagitis from the swallowing of corrosives it is better to defer the esophagoscopy until sloughing has ceased and inflammatory infiltration has bulwarked the weak places.

Mortality.—Of 206 cases of esophagoscopy for foreign bodies there were four deaths. One in a woman of 56 with advanced nephritis. The other three deaths were in patients admitted with severe lacerations of the esophagus from previous attempts at esophagoscopy. In 480 esophagoscopies for diseased conditions, there was no mortality. This included many cases in which specimens of tissue were taken esophagoscopically.

Dangers.—The danger of esophagoscopy in skilled hands is practically nil. Practice and training together with the careful passage by sight reduce the risks to those of anesthesia. In the hands of the unskilled anesthesia enormously increases the risk. Death may result from respiratory arrest due to compression of the trachea by the misdirected tube mouth, or by the esophagoscope over-riding a foreign body when the bulk of the intruder plus the bulk of the tube will compress the trachea through the soft "party-wall." Fatal instrumental perforation of the esophageal wall may occur, usually at about the cricoid level, the esophagoscope finding its way through the same weak spot through which the hernia known as a diverticulum occurs. The beginner may not recognize that he is outside the esophageal wall and may find his way down through the layers of the tissues into the mediastinum. Perforation may also occur either through a diseased or a normal wall in the mediastinum. The diseased wall associated with cancer is especially weak.

Instruments.—Esophagoscopes consist essentially of a tube of suitable length which serves as a speculum. Because of the length of tube required, special forms of illumination are necessary. These are of three classes: (1) A lamp with mirror worn upon the observer's head, as in Fig. 1152, page 532, Volume II. (2) An electric lamp with a prism or mirror for deflecting the illuminating ray and known as the Casper hand lamp is used by Gottstein, who has accomplished excellent results. Bruennings uses the same method of illumination as in his bronchoscope shown in Fig. 1153, page 532, Volume II., with a similar telescopic tube adjustable for length. One of the most favored instruments in Europe and one which is meeting with favor in America is that of Kahler shown in Fig. 2098. (3) The third form of illumination is by a small lamp close to the distal end of the esophagoscope. The great advantages of this method of illumination in having the source of light so close to the field to be illuminated, and in avoiding the loss of light inevitably due to the insertion of instruments in any form of proximal illumination, were first appreciated by Mikulicz, Gottstein, and Glucksmann. The Einhorn esophagoscope gave all of the advantages of distal illumination without any of the drawbacks and this form of lighting has become most popular in America. The esophagoscopes of Ingals, of Mosher and of the author all use this form of illumination, which was first devised by a mechanic, by the name of Preston, in connection with an urethroscope. As there seems to be but little difference between the results obtained by men of equal experience and skill using different forms of tubes and illumination, there is, doubtless, very much less importance to be attached to the particular form of instrument or illumination used than to the personal skill and experience of the operator. The esophagoscope used by the author is shown in Fig. 2099. For work in the upper end of the esophagus a very short tube may be used, but there are many advantages in using a speculum half of which is open at one side as shown at F, in Fig. 2099. All instruments to be passed through the esophagoscope must be of the least possible area of cross-section in order to

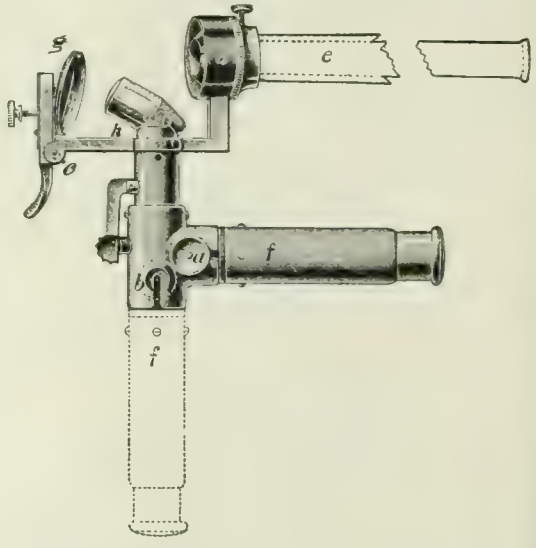


Fig. 2098.—Esophagoscope of Kahler. The light from the electric lamp, *h*, is reflected down the tube, *e*, by the mirror, *g*. This mirror can be moved out of the way for the introduction of instruments if desired though this is not always necessary. The handle, *f*, can be removed and inserted as shown by the dotted line.

obstruct the view as little as possible and in a case of proximally lighted instruments, to obstruct illumination as little as possible; because the absolute essential for safety in esophagoscopy is that every manipulation within the esophagus shall be done by sight, never blindly. Various accessory instruments are required such as aspirators, mop carriers for secretion, forceps with various forms of jaws for foreign body extractions, removal of specimens, exudates, etc. For the removal or morcellation of foreign bodies of different character, various special instruments have been devised and doubtless many more will need to be devised in the future to meet special problems. A convenient working set of instruments for esophagogastroscopy in ordinary cases is as follows:

1 adult's esophagoscope 10 mm. × 53 cm.
1 child's esophagoscope 7 mm. × 45 cm.
1 aspirator and tubing.
6 sponge holders.
2 forceps, 50 cm. and 60 cm.
1 double bronchoscopic battery with two cords.
1 thimble bite block.
1 mouth nozzle for aspirator.
12 extra lamps.

To this list should be added, though not absolutely essential, an adult's and a child's size esophageal

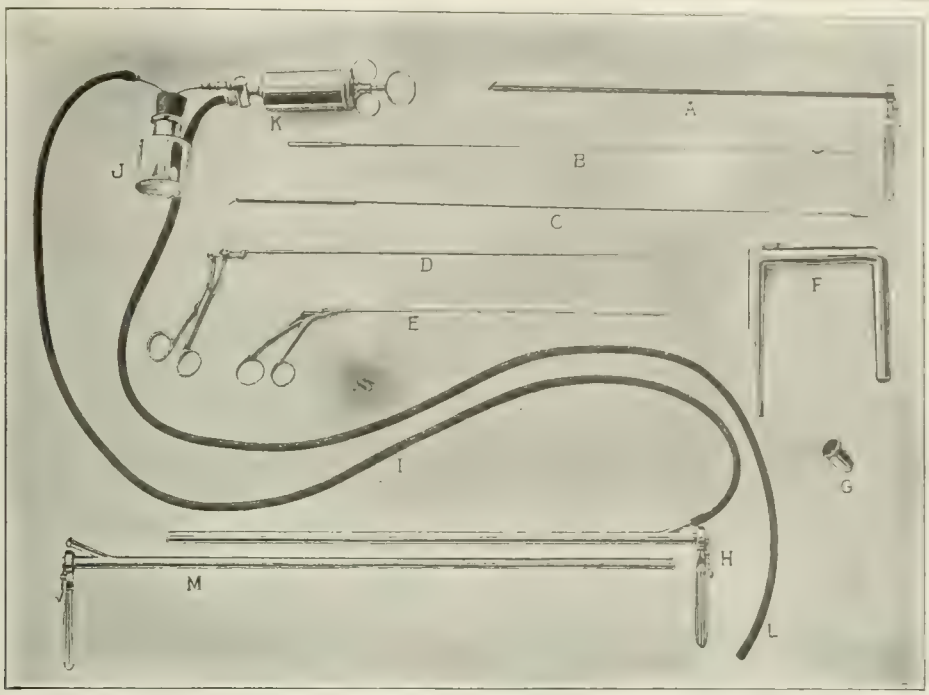


FIG. 2099.—Author's Instruments for Esophagoscopy and Gastroscopy. A. Slanted end esophagoscope for special purpose of finding a subdiverticular opening. B. Double olive bougie for starting dilatation of strictures of minute lumen. C. Sponge holder. D. Forceps for general purposes such as removal of foreign bodies. Only a short model is shown. E. Forceps for removing growths and specimens of tissue. A long cannula is fitted in using these forceps in the longer tubes. F. Esophageal speculum. G. Boyce bite block used to prevent patient biting the tubes. (A gag interferes with insertion of the esophagoscope by forcing the mandible downward.) H. Esophagoscope and gastroscope. I. Rubber tubing leading to aspirator. K. The tubing. L. gives positive pressure if needed for clearing obstruction in the drainage canal. M. Extra long tube (70 cm.) for gastroscopy in gastroptotic cases.

speculum and an elongated Mosher's alligator forceps for specular use.

FIG. 2100.—Radiograph, by Dr. George C. Johnston, showing an Artificial Denture in the Esophagus of a Man of 30 Years. Almost 90 per cent. of foreign bodies lodging in the esophagus are found at this location. Those lodging farther down are equally readily removable esophagoscopically.

RADIOGRAPHIC AID IN ESOPHAGOSCOPY.—While esophagoscopy gives all the certainty of direct vision, esophagoscopic work ought to go hand in hand with radiography and fluoroscopy. In foreign body cases location of the intruder not only as to its position in the esophagus but as to whether it is in the esophagus or in the air passages can frequently be determined by the radiograph, provided the foreign body is opaque to the ray (Fig. 2100). Whether opaque to the ray or not, every suspected foreign body case requires a radiograph, because the foreign body may not be the same as that of which we get a history. For instance it is quite common for the patient to state that a bone has been swallowed, when upon radiography, verified by extraction of the foreign body later, it is found that instead of the bone the foreign body is a pin or other substance which has accidentally gotten into the food. Furthermore in foreign bodies not opaque to the ray and which are large enough to be obstructive a bismuth capsule will be stopped at the location of the foreign body and thus definite data will be obtained. In all cases, however, where there is a negative ray in spite of a clear history of a foreign body being swallowed, an esophagoscopy should be done anyway. Fluoroscopic examination, while very much less reliable for foreign body work than a radiograph, is nevertheless most valuable in diseased conditions when used in connection with the shadow shown during the swallowing of the bismuth emulsion. Fluoroscopic guidance of the esophagoscope, in the removal of foreign bodies, is dangerous as compared to radiographic guidance. In diseased conditions a radiograph is essential in every case. Taken alone without esophagoscopy serious errors might occur as in the case illustrated in Fig. 2101.

PREPARATION OF THE PATIENT.—Except in cases of extreme emergency the patient should be prepared as for any operation by a bath, a laxative, and rest in bed. Whether general anesthesia is to be used or not, the

patient should be always fasted at least five hours before an esophagoscopy, in order that the esophagus shall be empty and the stomach as well, otherwise vomiting will seriously embarrass the procedure besides risking aspiration of food into the trachea. In stenotic cases no amount of fasting is certain to empty the esophagus. Therefore when we have a history of regurgitation of food some hours after eating, the patient should be induced to swallow a tumblerful of water and regurgitate it by titilating the fauces with the finger to produce regurgitation and in most instances this should be repeated a number of times in order to wash out the pouch or diverticulum, or dilatation which lies above a stenosis in almost all such cases. Should this be ineffective it is absolutely imperative that a general anesthetic be dispensed with because of the danger of tracheal pressure by an esophagus distended with food, and that the food be aspirated with the esophagoscope assisted by the pumping action of swabs introduced beyond the end of the esophagocope allowing the esophagoscope to fill and then pulling out the esophagoscope full of food by withdrawal of the swab. Illy masticated solids will occlude any form of aspirator. The mouth should be thoroughly cleansed, the teeth scrubbed with an abrasive tooth

Fig. 2101.—Radiograph, by Dr. Russell H. Boggs, of a Woman of 38 Years. The bismuth shadow, which so much resembles a diverticulum, was esophagoscopically proven to be a dilatation above a cicatricial stricture. The stricture was located above and behind the bottom of the dilatation. Esophagoscopic dilatation of the stricture resulted in complete and permanent cure.

powder or paste and the mouth thoroughly rinsed with thirty per cent. alcohol. In the case of adult, the fauces should be gargled with a ten or fifteen per cent. alcoholic solution in water.

Asepsis.—Because the field cannot be sterilized there is a great tendency to become careless in aseptic technique in esophagoscopy. It must be remembered, however, that so far as ordinary pyogenic organisms are concerned, the patient is more or less immune to those which he harbors himself while he may be extremely vulnerable to any such organisms introduced from without; and especially is it necessary to remember that the instruments used in esophagoscopy frequently encounter the specific organisms of lues, tuberculosis, pneumonia, diphtheria, and other diseases of the existence of which in a particular case the surgeon may be unaware. The only way to prevent with absolute certainty the carrying of such diseases from one patient to another is to carry out all the details of an aseptic technique in the esophagoscopy of every patient.

Anesthesia.—For esophagoscopy no anesthetic, general or local, is needed so far as the passing of the tube is concerned. The skillful esophagoscopist will pass the esophagoscope in any patientw hose mouth can be opened and whose esophagus is permeable, without any anesthetic, general or local. If desired, however, irritable fauces and lower pharynx in adults can be anesthetized with the local application of an eight per cent. solution of cocaine applied with a Sajous laryngeal forceps. The esophagus below the level of the hypopharynx is quite insensitive and it is altogether needless to use any local anesthetic below this point. General anesthesia while not necessary for the introduction of the tube is desirable in the following circumstances:

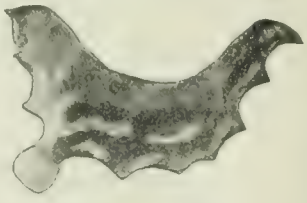


Fig. 2102.—Artificial Denture, Actual Size, Removed from the Esophagus of a Man of 30 Years, Bloodlessly, through the Mouth, by Esophagoscopy, without Anesthesia General or Local.

1. In case of very sharp foreign bodies which threaten perforation during the antiperistaltic movement excited by the presence of the esophagoscope.

2. Very large and sharp foreign bodies may be extracted when the esophageal musculature is completely relaxed by deep anesthesia, without the trauma incident to withdrawal through a spasmodically contracted lumen.

3. In very complicated removals such as the closure of open safety pins, disengaging, cutting or turning of double-pointed tacks, pins and the like, the work is greatly facilitated and risk of puncture is avoided by the relaxation and the abolition of reflexes incident to deep anesthesia. In working without an anesthetic the patient's fears must be quieted by explaining to him that the procedure is not actually painful but it is quite disagreeable and that he can make it very much easier for himself by relaxing instead of drawing all his muscles up tightly and rigidly as if he were walking upon ice. He must be told that he may feel a slight choking sensation as if his breath were being shut off, and that he must not be alarmed at this sensation because the operator will watch the breathing and that there is no danger whatever. In the case of children who are not amenable to reason it requires "team work" to do an esophagoscopy promptly, carefully, and safely without anesthesia (Fig. 2103). In fact this is the only way in which esophagoscopy can be done in children without any danger whatever. Cocaine is very dangerous in children under six years of age and general anesthesia introduces an element of danger out of all proportion to the risk in the general run of surgical cases. It is not the anesthetic, *per se*, but the fact that respiratory arrest occurring during esophagoscopy very often is fatal unless a tracheotomy or a bronchoscopic oxygen insufflation be done promptly. For gastroscopy deep general anesthesia is often needed, not for pain, for the procedure is painless, and not to facilitate the passage of the gastroscope because this can readily be done without any anesthesia, general or local, after the knack has been acquired; but in order to relax the diaphragm. When gastroscopy is attempted under morphine narcosis, as Mikulicz attempted it, the musculature of the

diaphragm closes upon the central tendon so that the gastroscope is guyed rigidly like a tent pole, consequently only such portion of the stomach can be inspected as happens to lie opposite the end of the tube mouth. To obtain free lateral movement of the gastroscope it is necessary to have the diaphragm completely relaxed by profound anesthesia. With the lens system instrument free movement is not so essential and quite an area of the stomach can be inspected by inflation. Under these circumstances, if the patient be not troubled with regurgitory movements, exploration can be made without any anesthesia or

Fig. 2103.—Manner of Controlling Child in Esophagoscopy without Anesthesia, General or Local. One nurse holds the knees down on the table. A nurse on the opposite side similarly holds down the hands. The assistant holds the head. The operator is shown about to introduce the esophageal speculum.

with cocainization of the pharynx only. The majority of patients, however, will keep up such a continual retching that general anesthesia will be safer. Henry Janeway has developed the use of nitrous oxide-oxygen anesthesia for gastroscopy.

Position of the Patient.—Esophagoscopy and gastroscopy can be done upon the sitting patient as shown in Fig. 1157, page 535, Volume II., and the esophageal speculum is often so used, but this position has the disadvantage of lessened controllability of the patient, troublesome cough from the overflowing of secretions into the larynx, and in foreign body work it has the great disadvantage that gravity works against the operator and in favor of the esophageal musculature in pushing the foreign body on downward. For practically all purposes the dorsally recumbent position of Boyce is to be preferred. The patient's head and shoulders project beyond the end of the table free in the air to be moved about as required by the operator and his first assistant who supports the head. To prevent fatigue the assistant holding the head supports his left arm on his right thigh as will be understood from the illustration Fig. 1159, page 537, Volume II., the left foot being elevated on a low stool the top of which is twenty-six inches below the top of the table. This is also the position for gastroscopy, though a few have used the lateral and the sitting positions.

Technique. Introduction of the Esophagoscope.—In order to introduce the esophagoscope two things must always be in the operator's mind. 1. The esophagoscope must be passed by sight, the eye never for one moment losing sight of the field so that the landmarks can be recognized as reached and so that the lumen ahead can be seen and its axis followed. 2. The thoracic esophagus goes backward as well as downward following the general curve of the [illegible] spine, therefore the head must be [illegible] 3. The head of the patient must be dropped to the level of the table in order to pass the esophagoscope through the hiatus at the diaphragm.

With the patient in the position described the head is held high above the table in full extension and the operator standing as shown in Fig. 2104, the esophagoscope is introduced through the right side of the mouth and the right pyriform sinus searched for. To find the right pyriform sinus it is necessary to understand the topographical endoscopic anatomy of the parts. Referring to Fig. 1, Plate XXXIII, the white vocal cords are seen in a state of spasmodic adduction, being more or less covered by the ventricular band. Posterior to this the aryepiglottic folds ending in the arytenoid eminences are seen in apposition; and below this (in the recumbent patient) the entrance to the esophagus is seen. The pyriform sinuses are at each side of this entrance to the esophagus. The cricoid cartilage presses on the rigid posterior wall of the pharynx supported by the spine and leaves no opportunity to get down in the middle line while at the side the pyriform sinuses (the normal food paths), are easily found to yield before the tube mouth. The right one is usually selected. In introducing the tube the arytenoid eminences are identified and the right one is particularly avoided lest the tube mouth hook over it. The tube mouth is pressed farther out to the right and anteriorward as it is inserted downward. The lumen opens up ahead as shown in Fig. 4, Plate XXXIII. The walls are collapsed together and do not open up very readily in the pyriform sinus. They often fold upward toward the observer as shown. Great care must be taken not to perforate the esophageal wall at the point of greatest weakness between the fundiform and the oblique fibers of the inferior constrictor muscle. There is always more or less spasm of this muscle and it is better not to be hasty but to wait for relaxation of the spasm. The coincidence of relaxation and a deep inspiration will help to open the lumen. It is a good plan in working without anesthesia or with local anesthesia to command the patient to take full deep breaths. After the tube mouth has followed from one to three centimeters, according to the age of the patient,

Fig. 2104.—First Stage in the Introduction of the [illegible] scope or Gastroscope. [illegible] pyriform sinus. The patient [illegible] above the level of the table.

the esophagoscope is directed toward the center line and readily enters the cervical esophagus (Fig. 5, Plate XXXIII), which is known by slight expansion during inspiration but a full collapse during expiration. In many cases no respiratory [illegible]

in the cervical esophagus. Passing on downward and following the lumen as it opens up ahead we soon enter the thoracic esophagus. This is known by the patulency of the lumen which does not close completely during expiration, as shown in Fig. 6 in the plate. In many patients a ridge will be noticed anteriorly at the crossing of the left bronchus. Passing on downward the tube begins to meet with some resistance when well down in the mediastinal portion, and if careful watch be kept on the lumen ahead it will be

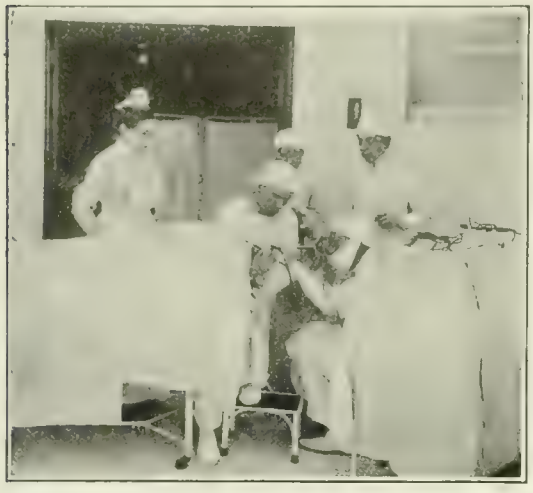


Fig. 2105.—Esophagoscopy. Position of operator, assistant and of patient's head and shoulders, during passage of esophagoscope through the hiatal and the abdominal esophagus.

found that the patient's head, and even the shoulders, must be dropped in order to follow the luminal axis in its anterior direction toward the hiatal portion of the esophagus (Fig. 2105). This change of direction occurs at about the junction of the middle and lower thirds of the esophagus; but it is unnecessary to determine the point by measurement since it is just a matter of following the lumen as it opens up ahead. When the hiatus is reached the esophagus will be found tightly closed usually by spasm of the hiatal musculature compressing the esophageal wall. This hiatal lumen may be a slit but more often it is a general sphincter-like contraction with radiating folds as shown at Fig. 7, Plate XXXIII. At this point it is necessary to have the patient's head toward the right and lowered until the vertex is slightly below the level of the table in order to give the axis of esophagoscope an anterior direction. In other words the operator points the esophagoscope as if aiming for a point in the air two or three inches above the left ilium. In this position slight pressure is made against the sphincter-like opening making sure that the opening is centered correctly in front of the tube mouth. The abatement of spasm is waited for, when the esophagoscope readily slips through and seems almost immediately to enter the stomach, the abdominal esophagus being about two or three centimeters in length. With the bright illumination of a distal lamp there is very little difference between the color of the stomach, when empty of food, and the color of the esophagus. With proximal forms of illumination the length of tube required to reach the stomach diminishes the illumination so that it seems very much more intensely red. The most important landmark for determining that the tube has entered the stomach is the shape of the folds which will be readily comprehended by looking at Fig. 8, Plate XXXIII. Usually clear fluid escapes from the normal stomach as soon as the tube mouth passes the hiatus.

Introduction of the Esophageal Speculum.—The patient being in a recumbent position, the esophageal speculum is grasped in the left hand while the patient's upper lip is held out of the way by the right hand so that the lip will not be pinched between the upper teeth and the speculum. The epiglottis is first identified, then the speculum is inserted about one centimeter farther and the epiglottis lifted strongly forward. This exposes the larynx which is seen in a state of spasmodic adduction as in Fig. 1, Plate XXXIII. The speculum is now moved over to the right exposing the right pyriform sinus, as shown in Fig. 2 in the plate. The speculum is then inserted down into the sinus when a strong lifting motion will lift the cricoid cartilage forward and expose the mouth of the esophagus. The most conspicuous landmark now present is the posterior lip of the mouth of the esophagus which extends forward seeming like a web closing up almost the entire posterior two-thirds of the esophageal lumen as shown in Fig. 3, Plate XXXIII. A better understanding of this posterior lip may be obtained from Fig. 10 in the plate, which shows a coin (half-dollar) jammed in the mouth of the esophagus while the posterior lip is being dragged posteriorly by the closed forceps. It requires care in the use of the speculum, as in all other esophageal instruments. Anything like roughness is sure to meet with disaster. The speculum may also be used in sitting patient as described for Direct Laryngoscopy, page 535, Vol. II.

Esophagoscopy for Foreign Bodies.—Of 206 cases of esophagoscopy for foreign bodies the intruder was removed in 198, escaped downward in eight. Thus it is clear that esophagoscopic removal of foreign bodies has now reached such a high state of perfection of technique that external esophagotomy with its high mortality is no longer a justifiable operation in these cases. Foreign bodies even of very large size that have gone down through the natural passages can be brought back the same way, provided the operator will turn them to the position of least resistance, as in a noted case in which Kyle removed a large artificial denture. In a few instances esophagoscopic morcellation may be necessary. The mechanical problems encountered in the removal of foreign bodies are al-

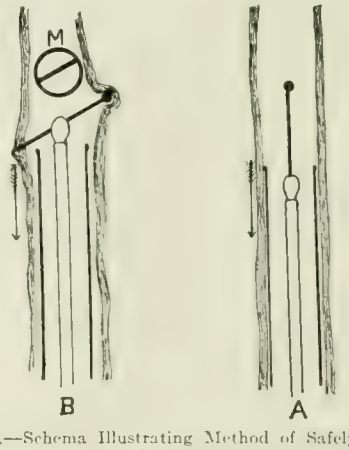


Fig. 2106.—Schema Illustrating Method of Safely Removing a Pin Esophagoscopically. The central part of the pin appears across the tube mouth as at M. If seized with the forceps and drawn in the direction of the dart the point will tear the esophageal wall in which the point is usually already buried. If, however, the wall is manipulated sidewise to the left with the tube mouth, the point will be disengaged from the wall and can be seized and harmlessly withdrawn through the tube as at *A*.

most endless, varying with the size and shape and location of the intruder. The general principle involved is that the foreign body must be so seized with the forceps that it will turn so as to offer the least resistance against removal, and also so that any sharp point that might cause trauma shall trail harmlessly

EXPLANATION OF
PLATE XXXIII.

EXPLANATION OF PLATE XXXIII.

ESOPHAGOSCOPIC VIEWS FROM OIL PAINTINGS BY THE AUTHOR.

1. Direct view of the larynx and laryngopharynx in the dorsally recumbent patient, the epiglottis and hyoid bone being lifted with the direct laryngoscope, or the esophageal speculum. The spasmodically adducted vocal cords are partially hidden by the overhang of the spasmodically prominent ventricular bands. The esophagoscope should be passed to the right of the median line into the right pyriform sinus.

2. The right pyriform sinus in the dorsally recumbent patient, the eminence at the upper left border corresponds to the edge of the cricoid cartilage.

3. The "mouth" of the esophagus in the dorsally recumbent patient, the cricoid cartilage being lifted forward with the esophageal speculum. The lower (posterior) half of the lumen is closed by the posterior lip of the esophageal "mouth," which advances spasmodically from the posterior wall. (Compare Fig. 10.) This view is not obtained with an esophagoscope.

4. Passing through the right pyriform sinus with the esophagoscope; dorsally recumbent patient. The walls seem in tight apposition and, at the edges of the slit-like lumen, bulge toward the observer. The direction of the axis of the slit varies.

5. Cervical esophagus. The lumen is not so patulent during inspiration as it is lower down; and it closes completely during expiration.

6. Thoracic esophagus. Dorsally recumbent patient. The ridge crossing above the lumen corresponds to the left bronchus. It is seldom so prominent as in this patient, but can always be found if searched for.

7. The esophagus at the hiatus. This is often mistaken for the cardia by esophagoscopists. It is more truly a sphincter than the cardia itself, and, in the author's opinion, it is questionable if there is any truly sphincteric action at the cardia. It is the spasmodic closure of this hiatal sphincter that produces the syndrome called "cardiospasm."

8. View in the stomach with the open tube gastroscope. The form of the folds varies continuously.

9. Sarcoma of the posterior wall of the upper third of the esophagus in a woman of thirty-one years. Seen through the esophageal speculum, patient sitting. The lumen of the mouth of the esophagus, much encroached upon by the sarcomatous infiltration, is seen at the lower part of the circle.

10. Coin (half-dollar) wedged in the upper third of the esophagus of a boy aged fourteen years. Seen through the esophageal speculum, recumbent patient. The posterior lip of the esophageal "mouth" is retracted by the forceps preparatory to removal.

11. Fungating squamous-celled epithelioma in a man of seventy-four years. Fungations are not always present, and are often pale and edematous. The appearance of malignancy may be masked by inflammation due to mixed infections.

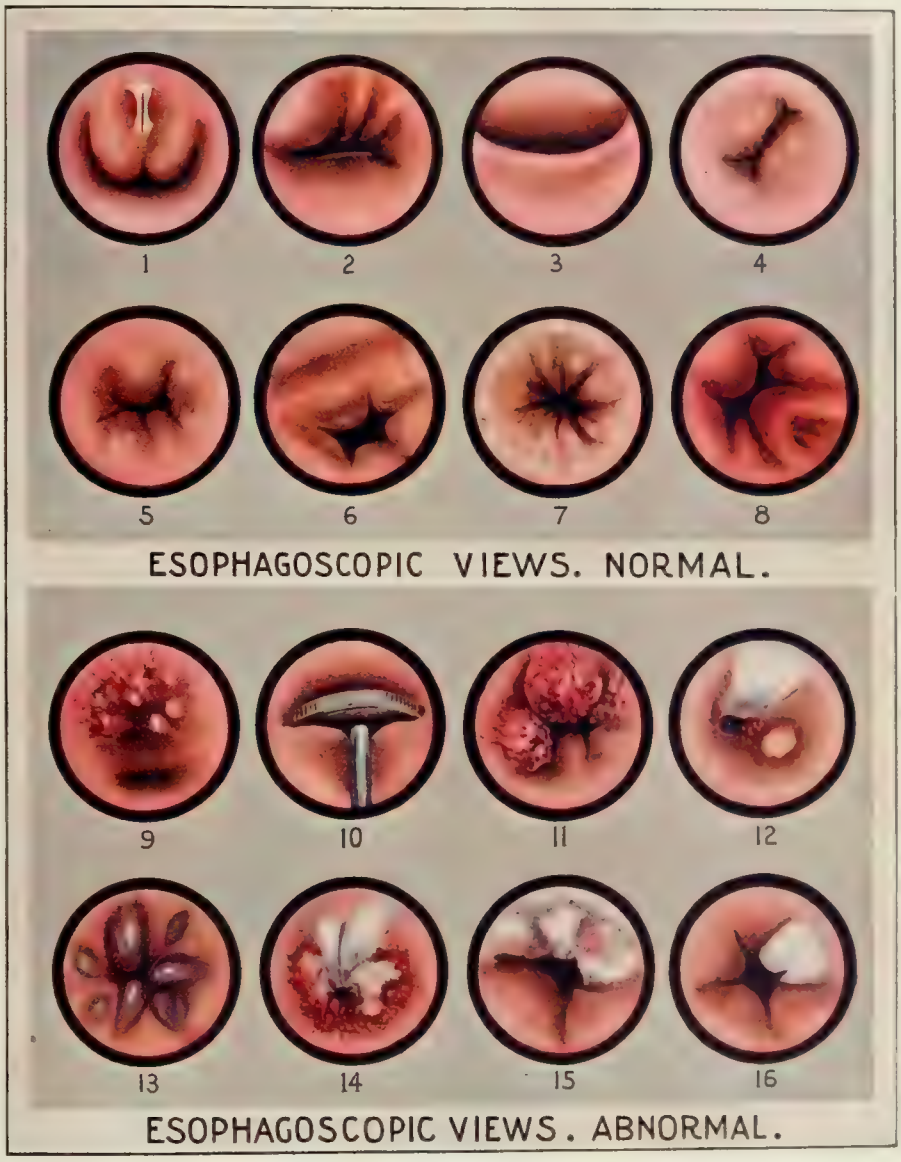
12. Cicatricial stenosis of the esophagus following the swallowing of lye in a boy of four years. Below the upper stricture is seen a second stricture. A third one not shown was located eccentrically farther down. An ulcer surrounded by an inflammatory areola and the granulation tissue together illustrate the etiology of cicatricial tissue. The fan-shaped scar is really almost linear, but is viewed in perspective. Patient was cured by esophagoscopic dilatation.

13. Angioma of the esophagus in a man of forty years. The patient had hemorrhoids and varicose veins of the legs.

14. Luetic ulcer of the esophagus twenty-six centimeters from the upper teeth, in a woman of thirty-eight years complaining of dysphagia. Two scars from healed ulcerations are seen in perspective on the anterior wall. Branching vessels are seen in the livid areola of the ulcers.

15. Tuberculosis of the esophagus in a man of thirty-four years. No vessels are visible near the grayish-white patches. A specimen of tissue removed esophagoscopically was found to be tuberculous.

16. Leucoplakia of the esophagus near the hiatus in a man aged fifty-six.



ESOPHAGOSCOPIC VIEWS

(From Old Pictures by the Author.)

behind during the withdrawal (Figs. 2106 and 2107). If, as often happens, the intruder is too large to be drawn into the esophagoscope, the foreign body, forceps and the esophagoscope can all be withdrawn together. When a safety-pin lodges point downward in the esophagus it can very readily be pulled into the esophagoscope so as to close it and prevent the point from wounding the esophageal wall. When, however, the safety-pin is lodged point upward, withdrawal

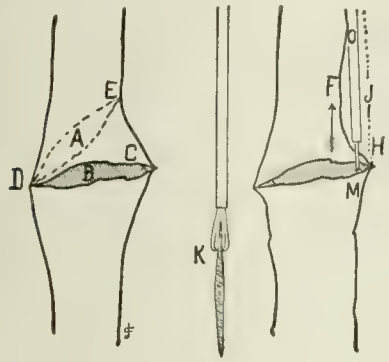


Fig. 2107.—Schematic Illustration of Safe Esophagoscopic Removal of a Sharp Splinter of Bone from the Esophagus. In process of being swallowed the bone, *A*, had lodged by its point, *D*. Pressure of food had forced the point, *E*, down to *C*. The points *C* and *D*, have almost punctured the wall. If the bone should be seized at *B* and withdrawn both walls would be lacerated with almost certain mortality. If, however, the in-bulging esophageal wall, *F*, is manipulated outward with the tube mouth to the position of the dotted line, *J*, disengaging the point, *H*, the forceps can be used to seize the bone at *M*. Traction being made in the direction of the dart the bone rotates to a position for harmless removal. To permit rotation, forceps touching only at the points (*K*) should be used.

with the forceps is certain to rip the esophagus, inflicting fatal trauma. A number of very ingenious methods of closing a safety-pin have been devised. A plan which has yielded excellent results is illustrated schematically in Fig. 2108.

Esophagoscopy for Disease.—The esophagoscope has revealed the fact that the esophagus is the seat of many diseases which were previously unrecognized and

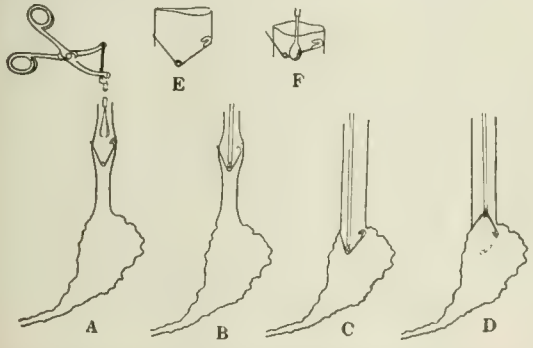


Fig. 2108.—Schema Illustrating Esophagoscopic Removal of an Open Safety Pin lodged Point upward in the Esophagus. *E*, *F*, show how the esophageal wall would be perforated by attempted withdrawal. *A*, *B*, *C*, *D*, show successive stages of a safe method of removal by passing the pin into the stomach, turning and removing by special forceps passed through the esophagoscope. The entire procedure is under guidance of the eye.

of many others, the diagnosis of which was made only hopelessly late in the pre-esophagoscopic days. Unfortunately, however, early esophageal symptoms are erroneously attributed to "globus hystericus," so that a spasmodic, luetic, tuberculous, malignant, cicatricial, or angiomatous stenosis is often [illegible] too late.

Esophagitis and Ulceration.—The [illegible] appearances in acute esophagitis are [illegible] ing in the early stages, edema in the later. If due to a corrosive, grayish exudates, [illegible] secretions may be seen. The treatment should not be by esophagoscopic application but by small doses of bismuth subnitrate swallowed dry on the tongue, with the occasional addition of small doses of [illegible] Chronic esophagitis usually appears as a [illegible] farinaceous coating which cannot be wiped off. Mucosa bare of this coating may be reddish or whitish in patches, with vessels visible in the paler areas. Superficial erosions may be present. Chronic esophagitis is usually associated with stagnation of food from stenosis, and consequent maceration by decomposition products. The treatment consists in the cure of the underlying organic or spastic stenosis. Ulceration of the esophagus consequent upon the same causes as chronic esophagitis is usually superficial, as is also the peptic ulcer occurring in the abdominal esophagus. The diagnosis of this and of simple ulcer will usually consist in the exclusion of lues by the usual means, and of tuberculosis and cancer by biopsy.

Compression stenosis of the esophagus is usually recognizable by the crescentic slit-like lumen of the compressed part and by the sensation of a mass external to the esophageal wall communicated to the esophagoscope. The compression of periesophageal tumors and glandular masses is hard; of aneurysm, soft. The pulsatory movement of aneurysm is often not more noticeable than that transmitted from the normal aorta. In spastic esophageal stenosis, as demonstrated on the author's cases by Boyce, there is frequently associated a dilated but not otherwise diseased aorta. In all cases of dysphagia in adults, aneurysm ought to be excluded by radiography, fluoroscopy and physical diagnosis, rather than by esophagoscopy. Compression from any cause may be associated with chronic esophagitis from stasis, or in the milder cases the mucosa over the mass and elsewhere may be normal.

Diffuse dilatation is always dependent upon a subjacent organic or spastics tenosis. The esophagoscopic appearances are those of chronic inflammation and maceration with a very much enlarged lumen. The remedy is the esophagoscopic cure of the stenosis. The dilatation, as shown by Jesse Myer, will probably persist, but progress and symptoms will cease.

Diverticulum of the Esophagus.—Traction diverticulum due to the inflammatory adhesion of the esophageal wall to periesophageal tissues in the mediastinum is a very rare condition, easily recognizable esophagoscopically by its form but usually unproductive of subjective symptoms. Pulsion diverticulum on the other hand is of very great importance and is curable. It is due to a hernia of the posterior or postero-lateral wall of the esophagus through the weakly supported point between the oblique and the fundiform fibers of the inferior pharyngeal constrictor. The propulsion of food while the lower fibers are spasmodically or even normally contracted herniates the superjacent, illy supported wall. Organic stricture may act in the same way as spasmodic constriction. When the esophagoscope is passed in this kind of diverticulated esophagus, the tube passes easily through a chronically inflamed lumen until it suddenly ends in a blind pouch the outlet of which is nowhere visible. Partial withdrawal of the esophagoscope and careful search of the anterior wall reveal the subdiverticular opening as a small slit, occasionally stellate, which is distinguished from a fold or pocket by the passage of a probe. The slanted-end esophagoscope is insinuated by means of its lip into the subdiverticular opening which is thus dilated. The dilatation is repeated until a cure of the stenosis is obtained, when the diverticular pouch should be amputated by the surgeon by external

operation. If the stenosis is allowed to remain the diverticulum is apt to recur. The esophagoscopist can render the surgeon great assistance by first pushing the pouch out into the wound; and then by inserting the esophagoscope into the subdiverticular lumen while the surgeon amputates the redundancy.

Cicatricial stenosis of the esophagus is usually due to the inflammation and ulceration following the swallowing of corrosive substances, such as solutions of lye, cleaning and washing powders, acids, etc. Stenosis may, however, follow traumatism of foreign bodies, breaking down of gummata, luetic, or tuberculous ulcerations. Cicatricial stenosis may follow even the ulceration and inflammatory infiltrations of the chronic esophagitis associated with spasmodic stenoses and thus convert a spastic into an organic stenosis. However caused, the diagnosis and treatment are accomplished by esophagoscopy with the safety and precision afforded by direct vision. The lumen of the stenosis is readily found and may be from a mere pin hole to a number of millimeters in size. As a rule any well-masticated food can be swallowed through a stricture of four millimeters lumen. The difficult cases are those of one or two millimeters. If there is active ulceration still present, as in Fig. 12, Plate XXXIII, no treatment should be undertaken until healing has been induced by the swallowing of frequent and small doses of bismuth subnitrate, aided, if need be, by the physiological rest of a gastrostomy with total abandonment of everything but water by mouth. Small strictures may be dilated with the author's dilator, Fig. 2109, placed under the esophagoscopic guidance of the eye. The instrument should be left *in situ* expanded for about fifteen minutes, the duration of the effect being in direct ratio to the duration of the dilatation. If the stricture is single it may be found easier to get a start with the double olive bougie, *B*, Fig. 2099. After a degree of dilatation has been obtained by either means, silk woven bougies may be placed by the esophagoscope which is then withdrawn and the bougie allowed to remain for fifteen or twenty minutes at each seance, the size of bougie being one or two numbers larger each time. All bouginage, as a safety precaution, should be done esophagoscopically by sight, never blindly. When size 20 (French) for a child, and 30 for an adult, has been reached the patient may be taught to pass the bougie himself by

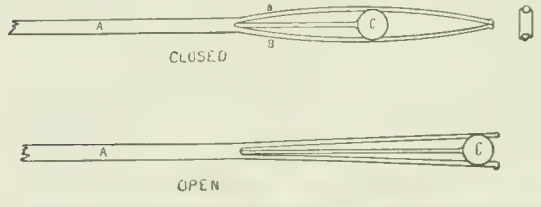


Fig. 2109. Author's Esophagoscopic Dilator for Esophageal Strictures. Especially useful in case of multiple eccentric strictures which are dilated successively from above downward. It is operated by attaching the handle of the forceps, *D*, Fig. 2099.

swallowing it, never by pushing. These and slightly larger sizes should be continued for a year or more. A stricture may be eccentric to the superjacent esophageal axis. Multiple strictures may be also eccentric to each other. These conditions render blind bouginage not only unsuccessful but exceedingly dangerous. In multiple strictures the upper one is dilated first, using the dilator Fig. 2109, until a small esophagoscope can be passed through, and the lumen of the next stricture thus found and dilated. A third and fourth stricture if present may be similarly dealt with.

Spasmodic stricture of the esophagus may occur in any part of the esophagus but the most frequent locations are in the abdominal and the cervical esophagus. In the cervical esophagus the fundiform fibers of the inferior constrictor contract in advance of the food; and also often at other times when they cause one form of the so-called "globus hystericus." Contractions of the abdominal esophagus were called "cardiospasm" until the author demonstrated esophagoscopically that the cardia is but very rarely concerned, the contraction taking place by the action of the diaphragmatic musculature at the hiatus, really a phrenospasm, or in some cases by the contraction of the entire abdominal esophagus throughout its two to four centimeters of length. Treatment by esophagoscopic dilatation of the spasmodically affected portion of the esophageal lumen is safe and the ultimate results are excellent in a large percentage of cases; though there are, in some instances, a number of relapses requiring repetition of treatment. The only incurable cases are those existing since childhood. A mechanical expanding dilator is used under guidance of the eye.

Benign neoplasms of the esophagus are very rare. When encountered their removal through the esophagoscope is readily accomplished. Recurrences are almost unknown.

Malignant disease of the esophagus presents widely varying esophagoscopic pictures. Endomural infiltration for a time is covered with normal mucosa. Carcinoma starting in the epithelium usually ulcerates early when all the local inflammatory evidences of the mixed infections may be present. Quite often edematous polypoid masses are seen. Fungations, usually quite vascular (Fig. 11, Plate XXXIII), though occasionally pale and edematous, are quite characteristic though not always present. Infiltration is the constant characteristic, and the skilled touch of the esophagoscopist will usually recognize it by the sensation transmitted by the esophagoscope. Taking a specimen is accomplished readily with the forceps, *E*, Fig. 2099. This procedure is quite safe, under ocular guidance, in fungating growths, but caution must be used in biting out the floor of a flat ulcer. The edge will be safer and by including a little normal will better enable the pathologist to give a dependable report. For the stenosis of malignancy, as a palliative measure, intubation tubes may be placed esophagoscopically in the cancerous lumen and thus delay the necessity for gastrostomy. Abbe, Sargnon, Hill, and others have had excellent results with the use of radium in malignant disease of the esophagus. A dosage equivalent to 200 milligrams of radium element is usually required; and this should be increased or diminished as local effect may indicate. The wall of the capsule containing the radium should be composed of at least one millimeter of metal, and both the capsule and the distal end of the esophagoscope should have a hard-rubber jacket to cut off the irritating secondary rays. The capsule must be placed with accuracy under guidance of the eye and must be kept in place for a period of one to eight hours with a rigid carrier in order that only the neoplastic tissue shall be in contact with the radium container. In its present stage of development there is nothing in the results of radium treatment to warrant neglect of operative treatment in any case deemed operable; but the effect on inoperable growths is encouraging, and future developments may extend its use to malignancy now deemed operable.

Gastroscopy.

Gastroscopy is an efficient and practical method for the diagnosis of stomach diseases, and especially for the recognition of malignancy at that early stage in which the surgeon may have a chance to cure a strictly local process. There can be no question as to the advisability of gastroscopy at the earliest possible moment in all cases in which malignant disease of the stomach is among the possibilities. Foreign bodies have been removed from the stomach and radium has been applied to inoperable gastric malignancy through the gastroscope. With the instru-

ments now available for gastroscopy the difficulties lie almost wholly in the esophagus and anyone who will devote to it the time necessary to learn esophagoscopy may with equal facility examine the stomach.

Fig. 2110.—The Gastroscope of Henry Janeway. *A*, Open tube; *B*, light carrier to be used during introduction; *C*, large lamp needed with lens system; *D*, lens system; *E*, window tube for using large lamp without lens system.

Results and Mortality.—The [illegible] by correspondence the results of 1 000 [illegible] copy by various operators and [illegible] practically nil in skillful hands. The only deaths attributable to the procedure were from perforation of the esophagus by various operators who had never learned esophagoscopy, and all were in the early days of gastroscopy before the absolute safety of the passage of an open tube by sight had been demonstrated by the author. The lesions diagnosticated were acute and chronic gastritis, ulcers, cicatrices, lues, gastroptosis, gastrectasia, carcinoma and sarcoma. Most of these lesions were located in the left two-thirds of the stomach but a few were at the pyloric end. The pylorus has been viewed in a few favorable cases, and even the duodenal folds, with the open tube gastroscope, *M*, Fig. 2099. It can be passed with safety into the stomach of any patient whose mouth, pharynx and esophagus are normal. Negative findings are of value only as applying to the area explored. In patients in whom the pyloric third is unexplorable, negative findings are to be classed with negative ophthalmoscopic findings in brain disease. Direct examination with the open tube permits of instrumental palpation, sponging and the removal of specimens of secretions and tissues. For indirect examination the lens system gastroscope of Janeway, Fig. 2110, is excellent.

Technique.—Preparation of the patient is the same as for esophagoscopy except that if there is defective gastric motility a much longer fast is necessary. Lavage is useful but must be done a few hours before gastroscopy in order to allow time for the absorption of residual fluid which is always inevitably left behind. As pointed out by the author, to get a correct conception of gastroscopic procedure and results, it is necessary to realize that the classic anatomic illustrations of the stomach are misleading as to both form and position. For gastroscopic purposes the stomach may be considered a loose, empty, collapsed bag of a form to fit whatever space is available at the particular time. The gastroscope is introduced by sight in precisely the same way as the esophagoscope. When the stomach is reached (Fig. 8, Plate XXXIII) with the open tube, the exploration begins at the extreme left of the stomach, by a vertical travel all the way down to the greater curvature, the head of the patient being to the extreme right. The tube mouth is now moved toward the right about two centimeters and withdrawn to the cardia, when it is moved another two centimeters to the right for another vertical downward travel. In this way the entire explorable area is examined as one would travel back and forth over a microscopical slide. The anterior and posterior walls are usually in contact and can be viewed at the same time as they separate ahead of the tube mouth. If the tube mouth seems to catch in the folds it can be freed by reversing the aspirator tubing, the window being inserted in the gastroscope. This gives positive pressure ballooning. The window must be removed from time to time if probing or sponging is to be done. Relaxation of the abdominal walls is facilitated by flexing the knees of the patient as shown by Henry Janeway. In some cases turning the patient over face downward causes the anterior gastric wall to drop forward, and in some instances this assists in exploring the pylorus by bringing it forward of the spine. In most cases a good [illegible] feel the tube-mouth through the abdominal wall and can bring the pyloric end of the stomach over to the middle line to be examined. If there is a mass at the pylorus it can be readily brought over unless there are extensive adhesions. In cases of gastric hemorrhage or of an exploratory operation the abdominal surgeon, with the hand in the abdominal incision, can have the gastroscopist report to him the interior appearance of any suspected tissue

which the surgeon can with the greatest ease place in front of the tube mouth. Cooperating thus the gastroscopist and the surgeon each have their sterile tables, instruments, assistants and nurses in two distinct sterile organizations. In gastroscopy with the lens system gastroscope the procedure is the same. The open tube is passed by sight and a local examination of the stomach is made. Then the

Fig. 2111.—Indirect View toward the Fundus with the Janeway Lens-system Gastroscope.

large lamp and the lens system are inserted, the stomach inflated with air or oxygen and a view obtained to the right or the left according to the direction in which the window of the lens system is placed. Orientation with a lens system is not easy; therefore the direction of the window as indicated by a fixture on the proximal end of the lens carrier should be constantly kept in mind. Good illustrations of the excellent views obtained through the Janeway gastroscopic lens system are shown in Figs. 2111 and 2112. For the taking of specimens of tissues or secretions,

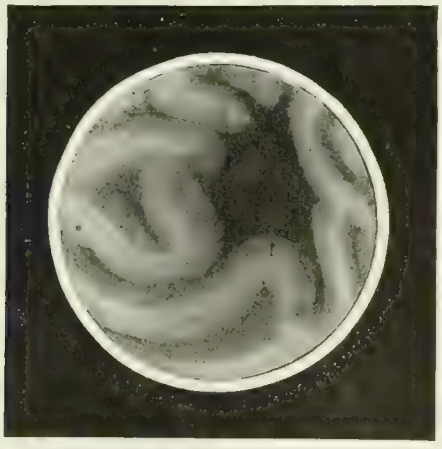


Fig. 2112.—View in the Direction of the Pylorus with the Janeway Lens-system Gastroscope.

probing, palpating, wiping, etc., the open tube is required. If during a lens system examination such manipulations are needed the stomach is deflated, the lens system removed and the suspicious spot searched for. For the taking of a specimen of tissue an extension of the author's forceps, *E*, Fig. 2099, is excellent. The results, dosage, screening, etc., of radium in its gastroscopic applications are the same as mentioned above for esophageal cancer. The open tube esophagogastroscope, *H*, Fig. 2099, is best for these applications. Chevalier Jackson.

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Esophagus, Anatomy, Histology, and Development of the.—The esophagus is the first portion of the tubus digestorius. It is a musculomembranous tube which extends between the pharynx above and the ventriculus below. It varies in length from twenty to thirty-five centimeters.

It begins, as the continuation of the pars laryngea pharyngis, behind the cartilago cricoidea at the level, in the adult, of the lower border of the sixth cervical vertebra, passes downward through the spatium mediastinale posterius in the thorax, then through the hiatus esophageus diaphragmatis into the cavum abdominis and opens at the level of the tenth or eleventh thoracic vertebra into the cardia ventriculi.

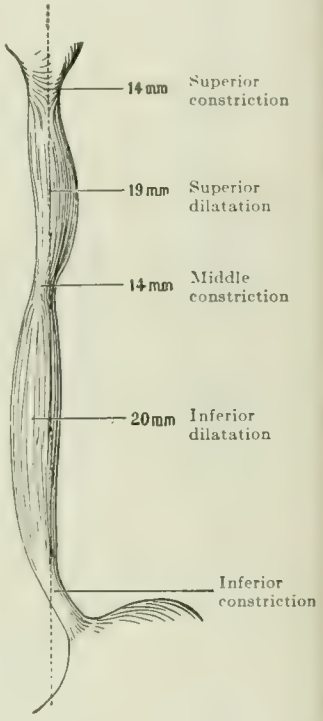

Fig. 2113.—Esophagus from in Front, with the Constrictions and Dilatations. Median line dotted. From a 21 year old male subject in which the esophagus had been hardened *in situ* by the injection of formalin into the arteries. (After Corning.)

By means of casts of the lumen of the esophagus there can be recognized both transverse flexures (to the right and to the left) and sagittal flexures, which correspond to the flexures of the columna vertebralis. The sagittal flexures occur with great regularity, while the transverse flexures, though in general quite constant, may vary in position and extent.

By referring to Fig. 2114 it will be seen that at its beginning the esophagus lies in the midline, but it soon bends to the left and reaches its maximum curvature at the level of the third cervical vertebra. At the level of the fourth cervical vertebra where the arch of the aorta crosses the esophagus it has regained the midline position which it maintains, with a slight curvature to the right, as far as the seventh thoracic vertebra, where it again bends to the left of the midline in order to join the cardia ventriculi at the level of the eleventh thoracic vertebra.

For general purposes, however, the esophagus can be considered a straight tube; that is in passing a sound no account need be taken of its flexures.

The esophagus can be subdivided into three portions: pars cervicalis, pars thoracalis, and pars abdominalis. The pars cervicalis extends from the sixth cervical vertebra to the second thoracic vertebra; the pars thoracalis extends from the second thoracic vertebra to the eighth or the upper border of the ninth thoracic vertebra where it enters the hiatus esophageus of the diaphragm; the pars abdominalis extends from the hiatus esophageus to the cardia ventriculi.

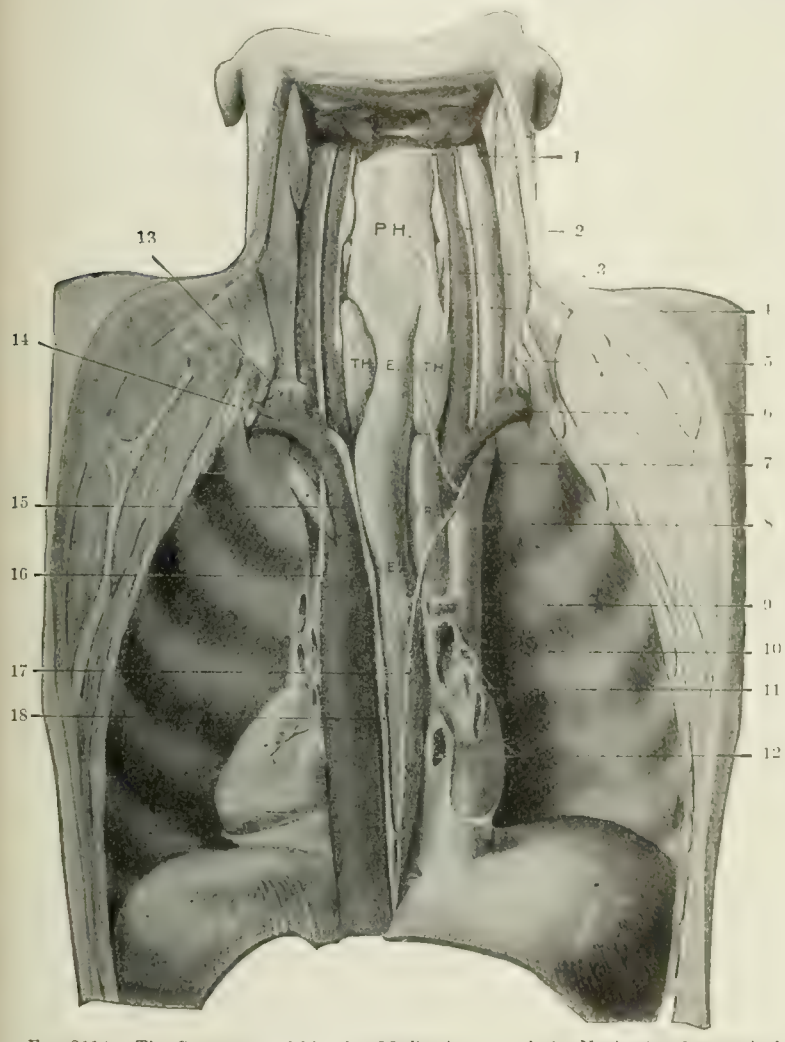

FIG. 2114.—The Structures within the Mediastinum and the Neck after Removal of the Columna Vertebralis and the Posterior Portion of the Cavum Thoracis. Viewed from behind. The structures were fixed *in situ* by injecting formalin into the arteries. From a 23 year old male subject. (After Corning.) 1, Pars cervicalis truncus sympathicus; 2, N. vagus dexter; 3, A. carotis communis dextra; 4, V. jugularis interna; 5, plexus brachialis; 6, A. subclavia dextra; 7, N. recurrens; 8, V. cava superior; 9, V. azygos; 10, bronchus dexter; 11, ramus dexter arteriæ pulmonalis; 12, Vv. pulmonales; 13, M. scalenus anticus; 14, A. subclavia sinistra; 15, A. et V. subclavia sinistra; 16, N. vagus sinister; 17, N. vagus dexter; 18, ductus thoracicus; PH, pharynx; TH, glandula thyreoidea; E,E', superior and middle constrictions of the esophagus.

The esophagus varies in diameter according to the height at which it is examined. Mouton, who obtained his measurements from plaster casts of the lumen, says that the esophagus varies from seven to twenty-two millimeters in diameter. These figures do not correspond to those obtained from the living subject. Corning obtained from bodies which had been fixed by injecting formalin into the arteries a set of measurements which may be taken as the normal (Fig. 2113). Merkel states that the position of the head has an important bearing on the size of the esophagus, especially in the cervical region, bending the head backward, flattening and at the same time narrowing the lumen of the esophagus.

While constrictions and dilatations have been observed in nearly all portions of the esophagus there are three fairly constant points at which constrictions are found and alternating with these constrictions are two dilatations (Fig. 2113). The first constriction is at the beginning of the pars cervicalis; the second is located at the bifurcatio trachea, at the level of the fourth thoracic vertebra, where the arcus aortæ crosses the esophagus; the third constriction occurs in that portion of the esophagus which passes through the hiatus esophageus of the diaphragm to enter the abdomen.

Immediately following the superior constriction is the superior dilatation. This extends through the lower cervical and upper thoracic regions and shows a well-marked curvature toward the left (Figs. 2113, 2114) which terminates, at the level of the fourth thoracic vertebra, in the middle constriction. The second dilatation extends from the fourth to the ninth thoracic vertebra and terminates, at the hiatus esophageus, in the inferior constriction. A second curvature of the esophagus to the left begins about the level of the seventh thoracic vertebra and continues to the end of the esophagus.

Foreign bodies entering the esophagus may lodge in the first constriction and, as this is situated at the level of the cartilago cricoidea, can be removed with little difficulty by operation. If they pass the first constriction they are most liable to stop at the second constriction. This is at the level of the second rib, so the foreign body is either at the root of the neck or just below the incisura jugularis of the sternum. If the foreign body passes the first and second constriction it will probably pass the third, because this is largely caused by the diaphragm and it relaxes to allow the foreign body to enter the stomach.

Measured, with the head midway between flexion and extension, the first constriction is situated fifteen centimeters, the second constriction about twenty-five centimeters and the third constriction approximately thirty-eight centimeters from the incisor teeth. In the cadaver the two upper constrictions can be dilated to eighteen or nineteen millimeters and the lower constriction to twenty-two millimeters in diameter. Some portions of the esophagus are capable of being dilated to thirty-five millimeters, but these figures should be applied with caution to the living individual. As a minimal measurement of the esophagus twelve millimeters in diameter may be considered the lowest normal figure.

"The most frequent seat of carcinoma of the esophagus is the middle third, where it bends somewhat to the left and is situated between the aorta and the beginning of the left bronchus which presents its cartilaginous wall, rather than its membranous portion, toward the esophagus. The esophagus itself diminishes in diameter in this region and its mucosa would, therefore, be more subject to abrasion at this point during the act of deglutition and to continued irritation following the abrasion" (Miller).

Blood-vessels.—*Arteries.*—In the neck the esophagus receives numerous small branches (rami esophagei) from the inferior thyroid (arteria thyreoidea inferior); in the thorax, arteriæ esophageæ from the aorta thoracalis, also some small branches from the arteriæ bronchiales; in the abdomen, branches (rami esophagei) from the left gastric artery (arteria gastrica sinistra) and occasionally some small branches from the left inferior phrenic (arteria phrenica inferior).

Veins.—The veins form a plexus on the exterior of the esophagus; from this plexus branches pass, in the upper portion of the esophagus, to the vena azygos and to the vena thyreoidea superior and thyreoidea inferior; in the lower portion, to the vena coronaria ventriculi.

By means of this varied distribution of its veins the blood returned from the esophagus is discharged, on the one hand, into the systemic circulation, on the other hand, into the portal circulation.

Lymphatics.—According to Sakata there are in the esophagus two networks of lymphatics, one of which is situated in the tunica mucosa, the other in the tunica muscularis. Sakata states that these two networks do not communicate with each other in the human esophagus; on the other hand, in the dog such communication exists, and it is probable that in complete injections of the lymphatics of the human esophagus communications between the two networks would be found. The lymphatics arising in the esophagus pass to the inferior set of deep cervical glands in the neck (lymphoglandulæ cervicales profundæ inferiores) and to the posterior mediastinal glands in the thorax (lymphoglandules mediastinales posteriores.

Nerves.—In the neck the esophagus receives its innervation from the nervus vagus by the way of the nervus recurrens; in the thorax and abdomen the innervation is from the nervus vagus and the systema nervorum sympathicum (Fig. 2114).

Topographical Anatomy.—*Pars Cervicalis.*—The pars cervicalis extends from the sixth cervical vertebra to the second thoracic vertebra. It is attached by loose connective tissue to the fascia prævertebralis, which covers the anterior surface of the cervical and thoracic vertebræ and also the MM. longi colli et capitis.

The pars cervicalis and the pars thoracalis, as far as the fourth thoracic vertebra, are covered ventrally by the trachea (Fig. 2115). Loose connective tissue extends between the esophagus and the pars membranacea of the trachea. By means of the loose connective tissue surrounding the esophagus a certain amount of lateral displacement or tortion is possible. In the interval between the trachea and esophagus may be found on each side the nervus recurrens, the left being the more superficial of the two, the right being completely covered by the trachea (Fig. 2115). On each side the lobi laterales of the glandulæ thyreoideæ may come in contact with the pars cervicalis.

The pars cervicalis does not lie in the midline, but bends so far to the left that its border projects beyond that of the trachea, making it more accessible for operative procedures than the right side.

The AA. carotides communes are situated at an increasing distance from the esophagus the higher they are followed in the neck, until, at the level of the lower border of the cartilago cricoidea, the lobi laterales of the glandulæ thyreoideæ are interposed between the arteries and the esophagus (Fig. 2114). The left A. carotis communis crosses the esophagus

Fig. A, at level of superior part of the 1st thoracic vertebra, shows the chief relations of the esophagus in the neck and also its divergence to the left.

Fig. B, at the 3d thoracic vertebra, shows the thoracic duct lying on the left side of the esophagus.

In Fig. C, at the level of the 5th thoracic vertebra, the left bronchus is seen in relation to the anterior surface of the esophagus.

Fig. D, at the level of the 8th thoracic vertebra, shows the pericardium lying on the anterior surface of the esophagus.

Fig. E, at the 9th thoracic vertebra, shows the esophagus inclining to the left just before piercing the diaphragm.

Fig. 2115.—Tracings from Frozen Sections to show the Relations of the Esophagus at the Levels of the 1st, 3d, 5th, 8th, and 9th Thoracic Vertebræ, respectively. A, Aorta; CA., carotis communis; D, diaphragm; LB, bronchus sinister; LC, A. subclavia sinistra; LR, N. recurrens sinister; LV, N. vagus sinister; Oe, esophagus; P, pleura; Pc, pericardium; RB, bronchus dexter; RR, N. recurrens dexter; RV, N. vagus dexter; T, trachea; TD, ductus thoracicus; VA, V. azygos. (From Cunningham.)

(Fig. 2116) at the level of the second thoracic vertebra, and at the level of the sixth cervical vertebra both Aa. carotides communes are situated about twelve millimeters from the esophagus. The arteria thyreoidea inferior extends, on each side, along the lateral border of the pars cervicalis to the glandulæ thyreoideæ. The trunci sympathici are situated, one on either side, about one centimeter from the lateral border of the esophagus in or under the fascia prævertebralis.

Pars Thoracalis.—The pars thoracalis extends along the anterior border of the corpora vertebræ from the second thoracic vertebra to the eighth or the ninth

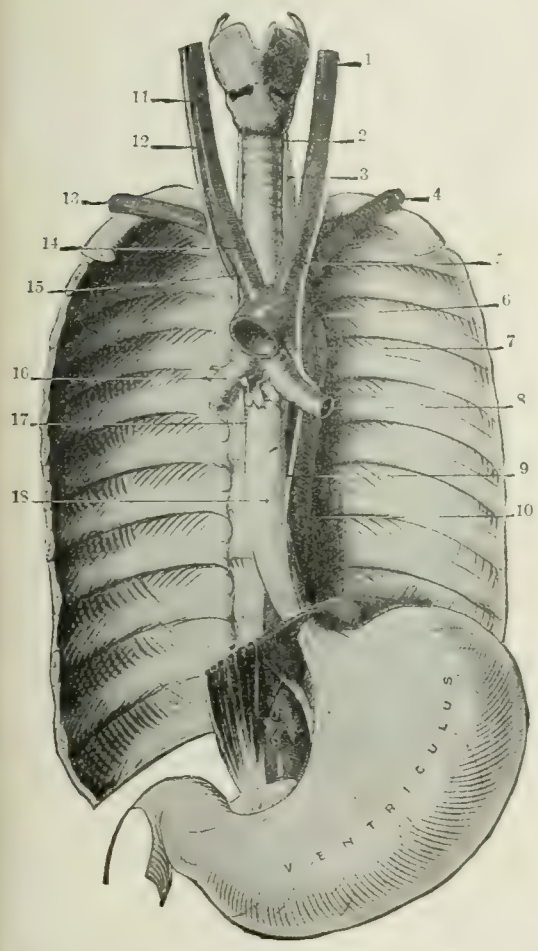

Fig. 2116.—Topography of the Esophagus, Trachea, Nn. Vagi and Aorta. Viewed from in front. (After Corning.) 1, A. carotis communis sinistra; 2, N. recurrens; 3, esophagus; 4, A. subclavis sinistra; 5, N. vagus sinister; 6, Arcus aortæ; 7, N. recurrens sinister; 8, bronchus sinister; 9, N. vagus sinister; 10, Aorta thoracalis; 11, A. carotis communis dextra; 12, N. vagus dexter; 13, A. subclavia dextra; 14, A. anonyma; 15, N. recurrens dexter; 16, bronchus dexter; 17, N. vagus dexter; 18, esophagus.

thoracic vertebra, gradually increasing its distance from the columna vertebralis until, where it passes into the hiatus esophageus, there is an interval between the two of from two to three centimeters. The aorta is situated at first to the left of the esophagus, but gradually approaches the midline passing dorsal to the esophagus in the interval between it and the seventh or ninth thoracic vertebra and reaching the midline position as it passes through the hiatus aorticus (Figs. 2114, 2115 and 2116). The relation between the esophagus and aorta is, however, subject to much variation, but the above described course may be taken as typical.

The arteriæ intercostales dextræ, which arise from the aorta thoracalis, cross the corpora vertebræ dorsal to the esophagus; they [illegible] thoracicus which lies in the groove between the aorta and esophagus and in the upper part of the thorax between the esophagus and the arteria subclavia sinistra (Fig. 2114). On the other hand, the arteriæ intercostales sinister have no relation to the esophagus.

Ventrally the pars thoracalis is covered by the trachea (Fig. 2115) as far as the fourth thoracic vertebra. At this level the left margin of the esophagus comes into relationship with the arcus aortæ and at a slightly higher level with the arteria carotis sinister and the arteria subclavia sinister (Fig. 2116).

Below the bifurcatio tracheæ the esophagus is in contact with that portion of the pericardium which corresponds to the atrium sinistrum. At this level the trunks of the nervi vagi, which have emerged from behind the two main bronchi, join the esophagus. The nervus vagus dexter passes along the dorsal wall of the esophagus accompanying it through the hiatus esophageus, and forms on the posterior surface of the curvatura minor the plexus gastricus posterior. The nervus vagus sinister passes along the left and anterior wall of the esophagus accompanying it through the hiatus esophageus and forms on the anterior surface of the curvatura minor ventriculi the plexus gastricus anterior.

In the upper part of the thorax only a portion of the left border of the esophagus comes in contact with the pleura mediastinalis. It is not again in contact with the pleura mediastinalis until just before it passes through the hiatus esophageus where it is covered by the pleura mediastinalis sinistra. On the right side it is not until the esophagus has reached a level below the radix pulmonis that its right border and a portion of its dorsal surface is covered by the pleura mediastinalis.

Many variations from the above description are met with. The absence of a dorsal investure by the pleura mediastinalis on the left side makes the esophagus more accessible by operation than on the right side because the pleura mediastinalis is more easily displaced.

Pars Abdominalis.—This extends from the hiatus esophageus to the cardia ventriculi. It measures from two to three centimeters in length. It is connected with the border of the hiatus esophageus by means of loose connective tissue and is completely surrounded by the peritoneum. It is in contact dorsally with the crus mediale sinister of the diaphragm, ventrally with the lobus caudatus and the lobus sinister of the liver. On the facies posterior of the latter it gives rise to the impressio esophagea.

The arteria phrenica inferior sinister as it passes from the aorta to the diaphragm is situated dorsal to the pars abdominalis. The nervus vagus dexter extends along the dorsal surface, the nervus vagus sinister along the ventral surface of the pars abdominalis.

Variations.—Corning states that variations of the esophagus may be caused by: (1) Changes due to age; (2) individual variations; (3) physiological changes in position due to pressure. It will be seen that the above factors cause changes in the diameter, curves and distensibility of the esophagus and may be intrinsic or extrinsic.

Malformations of the esophagus are occasionally met with as, for example, a double esophagus or an absence of the esophagus. Congenital diverticula are also found, but as yet no satisfactory explanation has been offered as to their origin. In a few rare instances a congenital fistula may be present, connecting the esophagus and trachea.

Development.—The esophagus is developed from that part of the primitive foregut which is situated

between the pharynx anteriorly and the ventriculus posteriorly. Like the remaining portion of the tubus digestorius its epithelium is of endodermal origin while its muscle and connective tissue are of mesodermal origin.

In its earliest stage of development the esophagus includes the anlage of the trachea; by the third week of embryonic life the trachea ("lung bud") appears as a separate growth, having been constricted off from the ventral side of the esophagus.

The esophagus grows rapidly. Hammar found in an embryo five millimeters long that it was 0.45 millimeter in length and that in an embryo ten millimeters long it was two millimeters in length; that is while the esophagus had increased in length nearly five times, the embryo had only doubled its length.

The older embryologists described the esophagus as having, in its earliest stage of development, an open lumen. This stage was followed by one in which the lumen was wholly or in part obliterated which was, in its turn, succeeded by a reopening of the lumen of the esophagus. Forssner, Schridde, and Johnson have studied the development of the esophagus and have failed to find an occlusion of the esophagus at any stage of development. The latest work available is that of Johnson and I shall draw freely from his paper in the following description.

In embryos of sixteen millimeters the esophagus has increased not only in length but also in breadth. The upper end is the larger and of irregular outline, while the lower end is smaller and of an oval outline. The mesenchyme which surrounds the epithelial tube is itself surrounded by a narrow ring of myoblasts which later develop into the stratum circulare of the tunica muscularis.

In embryos of nineteen millimeters "the epithelial tube is now irregular in outline and presents within its walls numerous small cavities or vacuoles." Some of these vacuoles open directly into the lumen of the esophagus while others are situated wholly within the epithelium (Fig. 2117, 1 *a*). These vacuoles are most numerous in the lower portion of the esophagus.

In a 22.8 milimeter embryo Johnson found that the esophagus was nearly twice the diameter of that in the nineteen millimeter embryo. The vacuoles were increased in number (Fig. 2117, 1 *b*) and communicated not only with the lumen of the esophagus but also showed a tendency to become confluent. From this stage on the vacuoles gradually disappear, beginning from above and progressing downward, until in embryos of thirty-seven millimeters they have entirely disappeared.

These vacuoles were first described by Schultze, and have been noted by Kreuter, Forssner and Schridde. The significance of the vacuoles is summed up as follows by Johnson: "Two results of vacuolation are, therefore, a destruction of the more superficial layers of cells, and an increase in the size of the lumen of the esophagus."

The epithelial tube is thrown into longitudinal folds at an early stage of development. There are usually four primary folds between which there are later developed smaller secondary folds. A dorsal fold is the first to develop and this is soon followed by a ventral fold. The second pair of primary folds develop from below upward. The secondary folds are less constant in position and size than the primary folds (Fig. 2117, 2, 3, 4 and 5).

The esophagus is lined with stratified squamous epithelium; but in embryos of the fourth or fifth month, and up to the time of birth, islands of ciliated columnar epithelium are found scattered throughout its length especially along the surface of the folds.

Johnson found in embryos of sixteen millimeters that the stratum circulare of the tunica muscularis was beginning to be differentiated. Schridde states that in embryos of 12.4 millimeters both the stratum circulare and the stratum longitudinale are well marked and that the stratum longitudinale (the last to be developed) is well developed throughout the entire extent of the esophagus in embryos of twenty-one millimeters. The lamina muscularis mucosæ is a later development and is not well defined until the embryo reaches a length exceeding ninety millimeters.

At the upper end of the esophagus the smooth muscle is replaced by striated muscle. The development of this mucle has been studied by McGill and

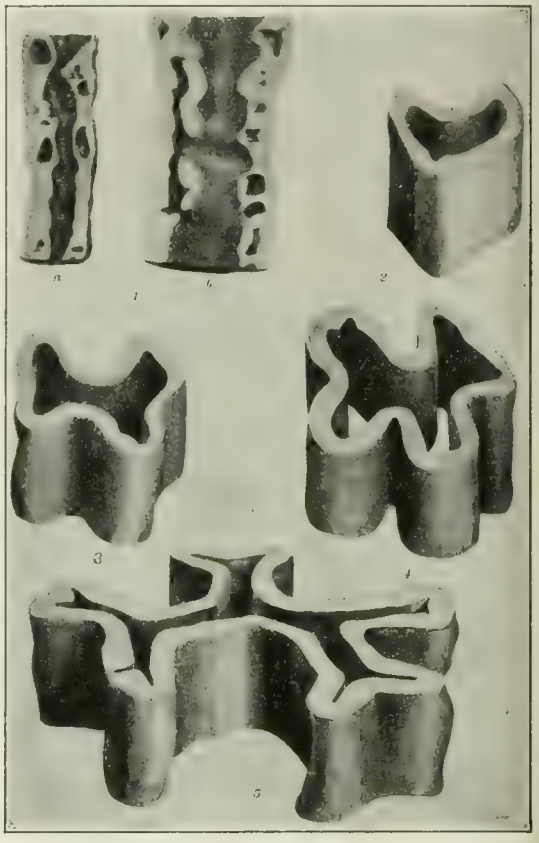

Fig. 2117.—Wax Reconstructions of the Epithelium of the Esophagus. 1, Showing vacuoles; *a*, human embryo of 19 mm. with discrete vacuoles; *b*, human embryo of 22.8 mm. in which the vacuoles have become confluent and some of them open into the lumen of the esophagus; 2, from a human embryo of 37 mm. shows single dorsal fold; 3, from a human embryo of 42 mm. shows dorsal and ventral folds; also beginning lateral folds; 4, from a human embryo of 55 mm. shows Greek cross stage; 5, from a human embryo of 120 mm. shows four primary and four secondary folds; the so-called Maltese stage. (After Johnson.)

the results may be summed up as follows: "The smooth and the cross-striated muscle of the esophagus arise from a common mesenchymal cyncytium. In the early stages, up to the time when the cross-striations form, both tissues appear identical in structure. The striated muscle of the esophagus seems to be only a further differentiation of smooth muscle. No transitional forms between the two tissues, however, were found in the adult esophagus."

Histology.—The walls of the esophagus are composed of four coats (Fig. 2118) which named from within outward are: (1) tunica mucosa; (2) tela submucosa; (3) tunica muscularis; (4) tunica adventitia. The tunica adventitia is replaced in the pars abdominalis by a tunica serosa.

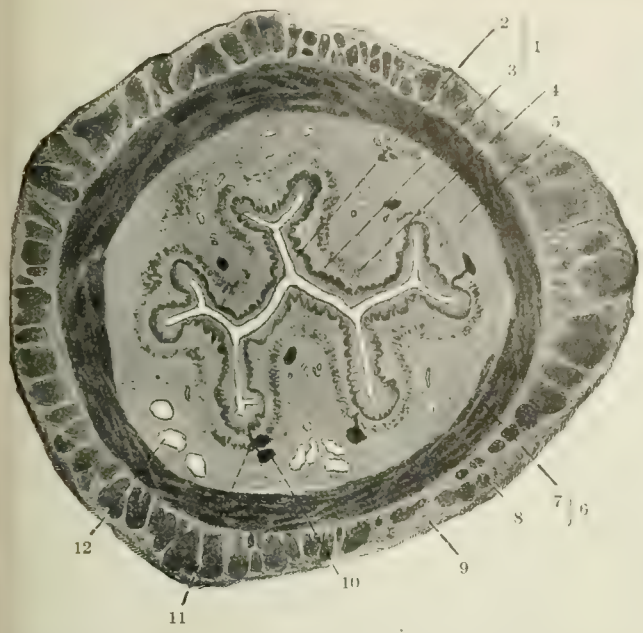

Fig. 2118.—Transverse Section of the Esophagus. (After Stohr.) 1, Tunica mucosa with its stratified squamous epithelium (2), and its lamina propria (3); 4, lamina muscularis mucosæ; 5, tela submucosa; 6, tunica muscularis with its stratum circulare (7), and its stratum longitudinale (8); 9, tunica adventitia; 10, vlandulæ esophageæ (mucous glands); 11, nodulus lymphaticus; 12, group of fat cells.

Tunica Mucosa.—The tunica mucosa can be divided into an outer layer of stratified squamous epithelium and an inner layer, composed of white fibrous connective tissue and a few elastic fibers, the lamina propria (Fig. 2118).

In sections cut transverse to the long axis of the esophagus the tunica mucosa is usually found thrown into longitudinal folds or rugæ and minute papillæ project from the lamina propria into the epithelium (Fig. 2118). A thin layer of smooth muscle, the lamina muscularis mucosæ, forms the outer boundary of the tunica mucosa (Fig. 2118). This is composed of bundles of smooth muscle arranged longitudinally. It is ill defined in the upper part of the esophagus but as the pars thoracalis is approached it becomes more distinct. The lamina muscularis mucosæ of the esophagus differs from that in the remaining portion of the tubus digestorius in that it contains only longitudinal bundles while both longitudinal and circular bundles are present in the other portions.

Noduli lymphatici are frequently found in the tunica mucosa; they are larger and often have a well marked germ center in the lower portion of the esophagus.

The *tela submucosa* (Fig. 2118) consists of loosely arranged bundles of white fibrous connective tissue and elastic fibers, which connect on the one hand with the connective tissue in the tunica muscularis and on the other hand with the connective tissue between the bundles of smooth muscle in the lamina muscularis mucosæ. Scattered groups of fat cells are also found in the tela submucosa.

Two varieties of glands (glandulae esophageæ) are found in the esophagus. The first consists of mucous glands which are situated in the tela submucosa with their ducts passing through the lamina muscularis mucosæ to open on the surface of the epithelium. The second variety of glands are situated in the lamina propria of the tunica mucosa and are found in the extreme upper and lower portions of the esophagus. The glands are of the branched tubular type. Their ducts often show dilations of greater or less size just before entering the [illegible] (Fig. 2119). The ducts and their [illegible] simple columnar epithelium [illegible] they open on the surface, [illegible] mous epithelium of the esophagus may be continued into them for a short distance. The glands of the upper group are sometimes designated as "the superficial esophageal glands of Hewlett," sometimes as "the upper cardiac glands of Schaffer." The glands of the lower group are called "the esophageal cardiac glands." They resemble the glands of the same name found at the cardia ventriculi. They are mucous secreting glands (Bensley).

The *tunica muscularis* consists, except in the upper third, of smooth muscle arranged as a stratum circulare and a stratum longitudinale (Fig. 2118). The two strata resemble in structure and arrangement the tunica muscularis of the digestive tract (see article in Volume III.), except that here each stratum is much thicker.

In the extreme upper portion of the esophagus only striated muscle fibers are present. Soon bundles of smooth muscle are found intermingled with the striated muscle and in the lower two-thirds only smooth muscle is present.

In the upper third (Fig. 2120) "the longitudinal fibers of each side, separating at the back, pass round toward the anterior aspect and form two longitudinal bands which run up on the front of the tube, and are attached by a tendinous band to the superior part of the posterior surface of the cricoid cartilage" (Cunningham).

The stratum longitudinale of the esophagus is often joined by narrow strips of smooth muscle, two of which are not uncommon. These are known as the M. bronchoesophageus and M. pleuroesophageus. The M. bronchoesophageus is a thin

Fig. 2119.—Part of the Tunica M[illegible] showing a Cardiac Gland with a D[illegible] the gland; 2, Lamina propria of the [illegible] of the epithelium; 4, columnar [illegible] lumen of the duct; 6, branched papilla from the lamina propria of the tunica mucosa projecting into the epithelium. (After Böhm and Davidoff.

triangular sheet of muscle which is frequently found arising from the posterior wall of the left bronchus and passing downward is inserted into the stratum longitudinale of the tunica muscularis of the esophagus. The M. pleuroesophageus arises from the connective tissue in the left half of the cavum mediastinale posterius, at about the level of the seventh thoracic vertebra, and extends along the aorta thoracalis and is inserted like the preceding muscle into the esophagus at a lower level. This last muscle is the more frequent of the two.

The *tunica adventitia* consists of loosely arranged areolar connective tissue and serves to attach the esophagus to the surrounding structures. As has been stated this is replaced by a tunica serosa in the pars abdominalis.

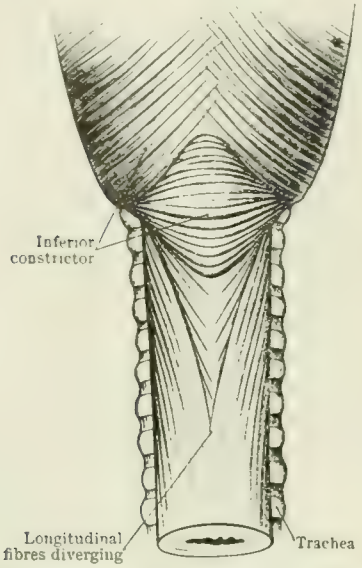

Fig. 2120.—Dissection to show the Arrangement of the Muscular Fibers on the Posterior Aspect of the Esophagus and Pharynx. Traced upward, the longitudinal muscular fibers of the esophagus are seen to separate posteriorly; passing round to the sides, they form two longitudinal bands which meet anteriorly and are inserted into the cartilago cricoidea. (From Cunningham.)

Blood-vessels.—The gross distribution of the arteries and veins has already been given. Beyond the fact that the larger vessels are found in the tela submucosa and that branches from these pass on the one hand to the tunica mucosa and on the other hand to the tunica muscularis, little is known in regard to the finer distribution of the blood-vessels to the esophagus.

Lymphatics.—The gross distribution has been described. Practically nothing is known at present in regard to their finer arrangement within the esophagus.

Nerves.—The nerves of the esophagus are derived from the peripheral and the sympathetic nervous systems. Branches of the nervus vagus are distributed to the striated muscle of the upper third while the smooth muscle and glands receive their supply from the sympathetic. Between the stratum circulare and the stratum longitudinale of the tunica muscularis of the lower two-thirds of the esophagus the sympathetic nerve forms a plexus which corresponds to that found in the same position in the tunica muscularis in the digestive tract (see this article).

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Esophagus, Surgery of the.—Surgical Anatomy and Physiology.—The esophagus begins at the lower border of the cricoid cartilage, opposite the lower border of the sixth cervical vertebra, and after passing through the hiatus œsophagi in the diaphragm ends in the cardiac end of the stomach opposite the eleventh thoracic vertebra. It averages about twenty-five centimeters (10 in.) in length beginning about fifteen centimeters (6 in.) from the teeth. Its course through the body is not direct, inclining first to the left in the cervical portion, hence in doing esophagotomy it is more easily reached from that side, it then inclines to the right reaching the median line again opposite the fifth thoracic vertebra, where it again passes to the left to pierce the diaphragm in front of the aortic opening and to the left of the median line opposite the tenth thoracic vertebra, and ends entirely to the left of the median line in the cardiac orifice of the stomach. It is accompanied through the diaphragm by both vagi nerves, and grooves the posterior surface of the liver near its termination.

Its lumen varies and is constricted at three points in particular: (1) at its commencement; (2) where it crosses the aorta and left bronchus; and (3) where it passes through the diaphragm. Its average diameter is about two centimeters. Moderate constriction will, therefore, be met with fifteen centimeters, twenty-two centimeters, and thirty-seven centimeters from the teeth line.

The arteries are branches of the inferior thyroid, posterior bronchial and phrenic arteries with a few direct branches from the aortic trunk and tributaries from the coronary artery of the stomach. The blood supply after reaching the gullet runs for the greater part longitudinally, which is a point of great importance in the nutriment a transposed part receives subsequent to evulsion of the organ. The veins empty into the azygos, superior and inferior venæ cavæ and portal veins. The nerves are derived from the pneumogastric, laryngeal, and sympathetic.

Relations.—*In the neck* the esophagus passes over the longus colli muscle and vertebræ behind, having

the trachea immediately in front; to the left it is in close approximation to the carotid sheath, the left lobe of the thyroid and the thoracic duct. The left recurrent laryngeal nerve is closer than the right, owing to the latter coming over from the right subclavian artery. It lies on the anterior surface of the esophagus near the left edge. The right carotid artery is farther away than the left and the right inferior thyroid artery is also farther away owing to the inclination of the esophagus to the left.

In the thorax the esophagus passes through the superior mediastinum between the trachea and its bifurcation in front and the aorta behind. It encroaches more on the left bronchus than the right. The arch of the aorta and subclavian arteries pass in front of it and in the posterior mediastinum the pericardium and diaphragm are anterior to it. Laterally it is in relation with the left pleura above and the right pleura below, the vena azygos major traverses its right side posteriorly. The aortic arch winds around its left side at the root of the lung. The right vagus nerve courses down its posterior aspect and the left vagus nerve its anterior surface forming a plexus on the walls. The relations of the crura of the diaphragm to the esophagus as it pireces this structure are of particular interest owing to the probable relation they bear to the etiology of idiopathic esophageal dilatation, or so-called cardiospasm.

Solid food is carried to the cardia by peristalsis, while fluids are pressed down by the contraction fo the mylohyoid muscles. The cardia is provided with a valvular and muscular mechanism preventing regurgitation under usual conditions, but in no way interfering with entrance of material into the stomach.

Methods of Examination.—These comprise inspection, palpation, percussion, auscultation, pressure determination, sounding, radiography, and esophagoscopy. The first three are of obvious importance, but demand no special consideration. In auscultating and esophagus the stethoscope is placed in the epigastric angle or along the spinal column and on liquid being swallowed a "squirting" murmur is to be heard almost immediately after the act of swallowing and is followed normally in six to seven seconds by a "squeezing" murmur as the food passes the cardia. This latter sound is changed in character, delayed or absent in stenoses or partial or complete obstructions of the canal, and is of great importance in the diagnosis of certain conditions especially incipient carcinoma near or at the cardia.

Pressure determination was earlier used extensively to ascertain the size of a dilatation, or the presence of a spasm or paralysis, but has been completely replaced by the data obtained from radiographic examination. Probably the most feasible method was that devised by Strauss, in employing a stomach tube to the lower end of which a rubber bag is attached, which after introduction into the esophagus was distended and the amount of air used computed. Its deficiencies are chiefly difficulty in introduction and the lack of definite conclusions which can be drawn in dilatations of small caliber. Von Mikulicz also devised a cumbersome and expensive apparatus which in application proved more academic than practical in the results obtained.

The use of sounds in experienced hands is of great value. Many varieties and modifications have been introduced, but are usually applicable to individual cases only. Four types which have proven general in the scope of usefulness are the (1) ordinary conical-tipped soft stomach tubes of varying diameters; (2) solid flexible bougies; (3) thin whalebone bougies with detachable olive tips of varying shapes and dimensions; (4) fenestrated detachable olive-tipped metal sound of Plummer, with spiral-tip attachment. Among others which have found application may be mentioned fenestrated hollow sounds, Crawcour's metal sound with spiral, Leube's and Stegel's [illegible] ticulum sounds, and many devised for therapeutic measures, as Schreiber's dilator, [illegible] Russell, Reichman or von Leube. [illegible] sound of Senator of Ebstein for the [illegible] laminaria tents, also von Hacker's apparatus for introducing thin catgut bougies.

Technique of Dilatation by Sounding.— Use the largest and softest sound first, preferably a stomach tube, no lubricant is necessary, the abundant mucoid secretions poured out into the throat being sufficient. Advance tube with head in natural position quickly to introitus of esophagus. The less time given the patient to realize what is being done the more readily will the introduction be accomplished. One or two endeavors to swallow causes the epiglottis to close, the musculature of the upper gullet to relax and the back of the tongue to force the tip of the entering tube into the introitus. Continuous gentle pressure should be made introducing tube one or two inches at a time only. When gagging or straining is present do not advance tube, but wait for interval. In introducing a solid flexible bougie start with head retracted until tip is at esophageal entrance, first having bent the tube in a curved shape, then allow head to come well forward and downward. All manipulation should be slow and without undue pressure.

From such sounding evidence may be gathered to indicate an inflammatory condition, if pain be a marked factor. This might be caused by an esophagitis, chronic or acute, or by an ulcer or tumor; should no contracting rings be encountered, atony or a phase of paresthesia might be inferred. It is well to remember that in some cases of cardiospasm with marked obstruction and dilatation a large tube may enter the stomach with ease. If the esophagus prove impassable to ordinary sounds, the method of Plummer with preliminary swallowing of thread and use of fenestrated olives is the most feasible. (See the section on Cardiospasm.)

Contraindications to the use of sounds are *local:* acute inflammation of the esophagus, manipulation after recent burns until four to six weeks have elapsed, hemorrhage; *remote:* advanced cardiac and pulmonary lesions, aneurysm and cirrhosis of the liver, owing to the esophageal varices frequently present in the latter condition.

Radiography affords opportunities of inestimable value in the diagnosis of esophageal lesions, not only as to their character, but also as to their position and extent. Concomitant fluoroscopy has been successfully employed in the removal of foreign bodies.

Technique.—The fencing position of Holzknecht should always be employed in radiographic examinations, namely, the rays should enter obliquely from the right side behind to the left side in front. This gives one an unobstructed view of the entire gullet. There is then administered a bismuth or barium meal consisting of from two to three ounces of bismuth subnitrate, or subcarbonate, or barium sulphate, incorporated with enough mucilage of acacia to make a paste of moderate consistency which is mixed into a glass of top milk and swallowed. The exposures are taken immediately. If data is required high up, it is best to make the exposures while the patient is still swallowing. Thus, defects in muscular contraction, the extent and position of various stenoses, and the position, degree and extent of any dilatation or diverticulum can be accurately shown. (See the sections on Cardiospasm, Stenosis, Diverticula, and Cancer.) Tumors themselves are frequently demonstrable as slight, usually irregular shadows, even without the use of bismuth. Aortic aneurysm is always recognizable although care must be taken to differentiate esophageal tumors which may have become adherent to the aorta and which through the transmitted pulsation simulate aneurysm closely.

Esophagoscopy.—*Direct.*—See the article on *Esophagoscopy and Gastroscopy.*

Retrograde.—The writer has inaugurated and employed this method of examination in cases where the epigastrium has been opened for exploration and has found it of the great value in cases where carcinoma of the lower portion of the esophagus is complicated by cardiospasm. By it the examiner can ascertain the exact position and extent of involvement and particularly the limits of gastric infiltration and there by be influenced in the choice of operation for its removal without subjecting the patient to the discomfiture of unnecessary oral introductions.

Technique.—A buttonhole incision is made in an avascular area of the gastric fundus which has first been circumscribed by a purse-string suture. An ordinary direct or indirect cystoscope of the Pilcher type is introduced and the stomach inflated with air through a Davidson syringe attached to the cystoscope. Accurate definition of all gastric, cardial, pyloric, and duodenal pathological processes may thus be obtained. At conclusion of examination the air should be evacuated and the purse-string suture drawn taut and inverted with a few Lembert sutures.

Congenital Malformations.—While extremely infrequent these are still of considerable surgical importance, probably not so much from an operative as from a diagnostic standpoint. The three usually met with in order of frequency of occurrence are (1) esophagotracheal fistula (2) obturation from membranous diaphragm and (3) stenosis.

Esophagotracheal fistulæ are symptomatized by attacks of asphyxia during swallowing, regurgitation of fluids through nose and mouth, or continued severe dyspnea from its entrance into trachea; foreign body bronchitis and bronchopneumonia are very likely to ensue, although many of the cases have survived some time; no attempts have been made to remedy the defect. Usually, however, the condition is only one evidence of other malformation which in themselves determine the mortality. Gastrostomy is the immediate rational treatment.

Obturation is immediately recognized owing to the inability of fluids to enter the stomach. Puncture of the obstructive membrane through an esophagoscope, is the best method of procedure. The diagnosis may be made by a radiograph, or by introducing metal sounds from above and below and then taking a radiograph. A coexisting esophagotracheal fistula may have to be dealt with.

Stenoses in the new-born are confined almost without exception to the upper portion of the esophagus. The diagnosis is determined through the clinical evidences of difficulty in deglutition and the presence of obstruction to sounding. The treatment is gradual dilatation. Diverticula are frequently found proximal to these stenoses and should be appropriately dealt with. (See the section on Dilatations.)

Injuries of the esophagus are occasioned from within by foreign bodies, sounds, and efforts of dilatation; from without by shot, stab, or incised wounds. In treatment of the former class absolute local rest is imperative and feeding must be accomplished either per rectum, via gastrostomy, or by stomach tube if its introduction is not hazardous. The prognosis is not particularly unfavorable unless the condition be complicated by mediastinitis which occasionally follows injuries received from without and should be treated by thorough drainage through a cervical or thoracic mediastonotomy, under differential pressure if necessary. Usually the outcome is determined by the injuries suffered by the other organs in the thorax. The diagnosis is usually made by the passage of particles of food through the external wound, or by coughing being evoked through irritation of the respiratory passages by the ingested material.

Wounds.—Here should be considered (1) rupture, (2) perforation, (3) hemorrhage.

Rupture has occurred from violent vomiting of large quantities of material, as the result of lavage, consequent to injuries or spontaneously, supposedly as the result of malacia produced by hyperacid gastric contents in conjunction with marked increase of internal pressure. Gottstein believes that spasmodic closure of the inferior pharyngeal constrictors is necessary before rupture can occur. This is probably especially applicable to the last class of cases. The symptoms are severe pain in the chest, repeated retching, inability to vomit or passage of fluids to the stomach, rapidly developing cutaneous emphysema of the neck and death usually within twenty-four hours. Treatment under differential pressure might prove efficacious.

Perforation may occur from within or without. As a rule, its development is gradual. The structures perforated intoare usually the large vessels, the mediastinum, or the lower air passages, and are the results of various esophageal lesions as ulceration proximal to stictures, or those the result of foreign body necrosis, or from traction diverticula and infrequently from cardial ulcers resembling in character the chronic gastric ulcers. The secondary perforations from without into the esophagus are the terminal results of pressure necrosis from aneurysm or necrotic process involving adjacent thoracic viscera. Diagnosis is to be made with certainty only in those cases involving the respiratory tract when by the method of Gerhardt, of noticing air passing through a tube introduced into the esophagus, one may be sure of communication of an air passage with the esophagus. The treatment consists of temporary gastrostomy and subsequent operation under differential pressure to disconnect the fistula and infold the esophagus, or to drain the mediastinum.

Hemorrhage from the esophagus may occur from carcinoma, ulcer, varix (the result of cirrhosis of the liver), burns, foreign bodies, perforation and from ruptured aneurysm. When profuse it is particularly fatal. Its source can only be ascertained, and that with the greatest difficulty, by inspection through the esophagoscope, or through retrograde esophagoscopy after the author's method, and attempts may be made to tampon it through this instrument, symptomatically astringents as iron, adrenalin, styptol, ergot, ice, etc., have been suggested but are seldom effective. The bleeding area may be compressed by an inflated rubber bulb, or the use of such an instrument as Schreiber's dilating bougie.

Foreign bodies in the esophagus form by far the largest class of surgical affections of that organ, as practically anything which can pass through the pharynx may become lodged either permanently or temporarily in the esophagus. Such bodies become of clinical interest only when they become impacted, and thus interfere with deglutition or cause pain or produce complications through puncture of the walls or initiate stricture formation.

Predisposing causes to the lodgment of foreign bodies in the gullet are loss of teeth, or paralysis of the facial muscles, lips, tongue, pharynx, or esophagus, various inflammations of the postbuccal region, also strictures, growths, malformations of the organ, youth, and insanity.

Sites of election are usually at the points of physiological constriction, namely, at the level of the cricoid, at the point where the left bronchus crosses the gullet and above the hiatus œsophagi.

Symptoms are varied and may range from practically no discomfort to nausea, vomiting, or pain on deglutition, dyspnea, or even asphyxia. Much depends on the character of the ingested body or its position in the gullet. Stabbing pain usually denotes puncture of the mucous membrane. Again, merely a feeling of re-

trosternal pressure may be experienced. The pain complained of does not always correspond to the level of the impacted body, and may even be due to the injury inflicted by the body in passing.

Diagnosis may usually be most readily made by the history and by a consideration of the subjective symptoms. Occasionally one can palpate a large body by lateral pressure on the neck, or through digital palpation through the pharynx. The introduction of a soft tube, probang or bougie, may locate the level of the obstruction, but the greatest caution must be exercised in the blind introduction of these instruments, as perforation has been repeatedly caused in this manner, or the object dislodged from a favorable position above the level of the crossing of the bronchus to one below it, which situation is much less accessible, or it may be caused to become more firmly impacted. This method would best be reserved for use only in those cases where soft objects form the obstruction, in some of which instances the manipulator may be successful in pushing the body on into the stomach or possibly have it ejected through the efforts to vomit which may be stimulated. Radiography or fluoroscopy have proved of the greatest value in locating objects refractive to the passage of the rays. The transillumination or photograph should be taken in the fencer position. A most striking illustration of the possibilities of the detail thus obtainable is well shown in Fig. 2121.

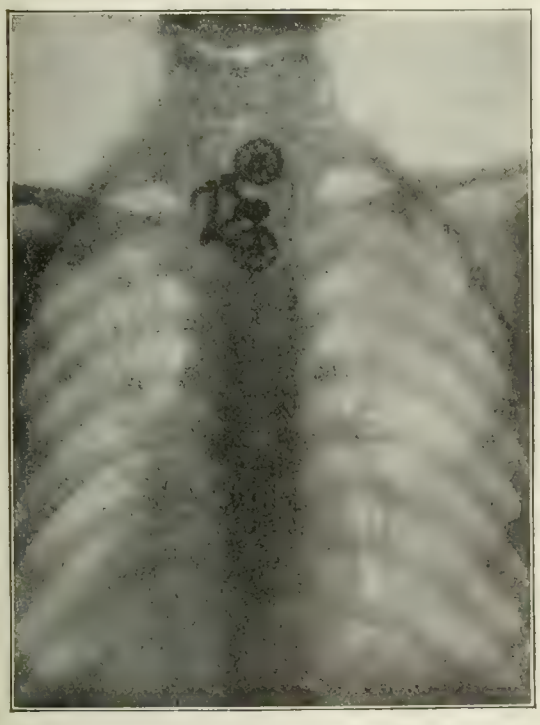


Fig. 2121.—Toy Bicycle Lodged in Esophagus. (Rigby)

The most successful method, however, at our command both from the point of diagnosis, as well as treatment of foreign bodies lodged in the esophagus, is esophagoscopy (*q.v.*).

Treatment should never be instituted until the most exhaustive efforts have been made to not only verify the diagnosis, but to ascertain to a certainty the situation and nature of the obstruction and its relative position within the canal. The treatment may consist of either non-operative or operative measures.

Non-operative Extraction.—In cases where the obstruction causes asphyxia, it is always situated at the introitus of the esophagus and can either be removed by the finger, or by a pair of [illegible] Tracheotomy must occasionally be performed as a temporary measure. The practice of [illegible] has been referred to incident to the [illegible] bougies and its indiscriminate use cautioned against. If it is indicated, however, it may be [illegible] injections of tobacco, as suggested by [illegible] podermic injections of apomorphine, or probably best by titillation of the uvula. When the obstructing substance is of such a nature as to lend itself to digestion or shrinkage, the former may be [illegible] administering a solution of pepsin or papain and hydrochloric acid, or the latter by having the patient drink strong cognac. Many instruments have been devised for the removal of foreign bodies from the esophagus. Among them may be mentioned the forceps designed by Gutsch, Eckholdt, Bond, Burge, Cloquet, Cusco, Mathieu, and Gama. Other instruments used are Petit's hook, Graefe's coin-catcher, or the ring coin catcher. These have all been used repeatedly and successfully, as have the bristle probang and the horsehair parasol snare in many instances. The simpler methods failing, recourse must be made to the esophagoscope. Many instances will occur where even manipulation through this instrument will prove ineffective and open operative intervention indicated.

Operative Removal.—This resolves itself into five methods of approach according to the situation of the foreign body (1) esophagotomy (high) (2) esophagotomy (low) (3) gastrotomy (4) cervical mediastinotomy (5) posterior thoracic esophagotomy. The technique of these procedures will be considered later on under the caption of operative methods.

Complications depend greatly on the size, nature, and situation of the foreign body. Probably the most frequent immediate trouble is that caused from hemorrhage which is particularly difficult to control when profuse. Direct ligature or tying of the carotid in the lower third has been suggested. Empyema, pyopneumothorax, local abscess, pericarditis, openings into the trachea and bronchi and even into the thoracic aorta have occurred from perforation at the site of impaction due to the resultant necrosis; esophageal fistulæ have also been formed.

Prognosis is relatively bad if the object is not removed early. Cutaneous emphysema is almost invariably followed by a fatal issue, while in all cases of abscess formation the prognosis is unfavorable. The usual operative measures for their relief are of course indicated.

Esophagitis.—Local inflammation of the gullet may be produced through chemical, thermal, or mechanical processes, or be sequelæ to some of the exanthemata. The most important of this class may be termed

Toxic or corrosive esophagitis, caused by swallowing caustic soda, lye, or acid, may be either superficial or deep in character usually dependent upon the degree of concentration of the substance ingested. (Fig. 2122.) The diagnosis is usually made from the history and buccal inspection. The treatment should be immediate and thorough. If possible to introduce a stomach tube easily, the stomach should be repeatedly flushed out with the antidote for the poison taken; thus, in cases of acids, an alkali should be employed, as soap solutions, sodium bicarbonate, calcined magnesia (wall plaster), or food given to bind and thus render inert the irritant, eggs, or milk, or both are the best to use; sweet or olive oil is indicated as it serves to protect the mucosa from further injury. When the poison is of an alkaline nature, as in the use of lye, or caustic soda, acids should be administered—probably best dilute vinegar—and then the use of milk and oil. As a result of the more severe corrosions,

there may follow complete occlusion of the esophagus, or the stomach may be in so precarious a condition as to not tolerate any material in it, or a complete occlusion of the pylorus may result. The surgeon must be guided, therefore, according to the situation and extent of the lesion as to whether a gastrostomy or jejunostomy is imperative. The interval treatment is purely symptomatic. Sounds should under no consideration be used until after one month has elapsed, best wait six weeks, and even then they

Fig. 2122.—Radiograph of Cicatricial Stenosis Caused by Lye. Note the smooth margins and the proximal dilatation of the esophagus.

should not be employed if there is any fever or evidences of active inflammatory reaction in the esophagus, as tenderness, pain, blood streaks, in vomitus or saliva.

Acute catarrhal esophagitis is also quite frequently encountered following the ingestion of very hot fluids, or as a result of sounding, or the swallowing of foreign bodies, and is symptomatized by fever, lancinating pain on deglutition and a viscid tenacious secretion. The treatment is symptomatic and prompt recovery in a few days usually ensues. No local instrumentation should be used.

Phlegmonous esophagitis is of rare occurrence. Its etiology is given as being the resultant of foreign bodies, corrosions, phlegmon of the stomach, rupture from the periesophageal purulent foci, and lacerations of the mucous membrane after violent vomiting. A diffuse and circumscribed form are described. The diagnosis is seldom made. The symptomatology consists of fever, chills, dysphagia, dyspnea, and purulent expectoration. The prognosis is unfavorable. Treatment resolves itself into drainage of the foci, if they can be located, either by puncture or by incision of the mucosa through an esophagoscope.

Chronic catarrhal esophagitis may either originate as such, or be the result of an acute process. It is frequent in chronic alcoholism and in habitual smokers, or may be associated with adjacent chronic processes of a similar nature of the pharynx or stomach. A more or less severe grade is usually present in most all mechanical conditions affecting the gullet as stricture, diverticula, or spasm, and is frequently present due to passive congestion in cardiac, renal, and hepatic disease. The symptoms are slight and usually merely a burning sensation of mild character in the esophagus is experienced, accompanied by occasional transient interference with deglutition.

In this category might well be considered those affections of the esophagus noted after some of the acute contagious and infectious diseases as diphtheria, scarlet fever, typhoid, small-pox, thrush, etc., in which infiltration of the tissues to a moderate degree occur and occasionally pseudomembranous casts are desquamated. Local cleansing with weak boric acid solutions (three per cent.), and removal of obstructing masses with a stomach tube or soft mandarin, or by the induction of emesis, is usually all the condition requires.

Ulcers and Fissures.—The former are usually of superficial character and consequent to an associated chronic inflammation. The chronic perforating type is considered under wounds of the esophagus. The treatment of the class considered here is chiefly rest, local applications of stimulants, as silver nitrate on a swab introduced through an esophagoscope, and the administration per os of bismuth subnitrate or subcarbonate. Fissures are usually the result of instrumentation, or the passage of foreign bodies, and are located at the points of physiologic constriction, more frequently at the cardia probably than elsewhere, in which situation they occasionally cause local spasm, for the relief of which applications of silver nitrate, ten per cent., and bismuth may suffice, or even temporary gastrostomy may have to be performed in the more resistant and troublesome conditions.

Motor Disturbances of the Esophagus.—These are encountered probably more frequently even than the occurrence of foreign bodies, when their symptomatology is appreciated and the proper measures instituted to assist the examiner in making a correct diagnosis. Those phenomena will be considered which result from acute, intermittent, or continuous spastic contraction of the esophageal musculature in varying locations in the organ and of types presented which may be either the result of functional or organic disturbances.

There are some other disturbances of the esophageal musculature in the nature of complete or partial paralysis which are much more rare in occurrence.

Esophageal paralysis has occurred as one of the sequelæ of diphtheria, in the course of hemorrhage, softening, tumor or sclerosis in the brain, pressure from enlarged lymphatic glands on the vagus nerve, disease of the vertebræ, chronic alcoholism, lead poisoning, and syphilis. The condition is symptomized by immediate regurgitation of ingested material, disturbance of the swallowing sounds is to be noted, and radiographic examination shows evidences of atonic dilatation. The treatment resolves itself into feeding through a tube and treatment of the causative factor. The prognosis is not essentially bad.

Esophagismus, or spasm of the esophagus, when considered as an entity, is a relatively common condition. This is particularly pertinent in the paroxysmal type. It may be conveniently classified relative to anatomic distribution into (1) cricoid spasm, (2) spasm of esophagus proper, and (3) cardiospasm. Relative to its etiologic factor the classes of (1) idiopathic, (2) reflex, and (3) tonic spasm should be considered.

Cricoid spasm is probably the most frequent of occurrence, and is a term introduced by the writer to denote a contraction of the circular muscular fibers at the introitus of the esophagus which is in close relation to the cricoid cartilage. Its etiology is more

commonly neurotic in its nature, but severe and protracted cases are also found in smokers and alcoholics in whom there is usually an accompanying chronic esophagitis. Tuberculosis of the larynx, or other local inflammatory processes frequently cause cricoid spasm as do ulcers, strictures, tumors, or fissures lower down, the so-called globus hystericus is merely a common name for this condition. The diagnosis is usually easily made in the absence of any other local trouble. On direct esophagoscopic examination the introitus appears as a firm, tight rosette. Passage of a sound or stomach tube frequently allows the examiner to experience the sensation as if the instrument were passing a narrow canal; occasionally the muscle will grasp the tube spasmodically. The symptoms consist of retromanubrial cramps with radiation to the shoulders and back of the neck, and a more or less severe grade of dysphagia according to the condition. Occasionally swallowing is impossible, but one of the characteristic signs is the varying degree of permeability present at short intervals. The condition tends to recur frequently. The treatment consists of sounds, dilatation, electricity, local and general analgesics, and sedatives.

Esophageal spasm, or contraction of the entire esophagus, is frequent but usually of a very transitory nature. It is invariably preceded by spasm at the introitus and its etiology and treatment coincides with that of pathological muscular contraction at that point as previously described. The symptoms differ in that the cramp begins at the level of the

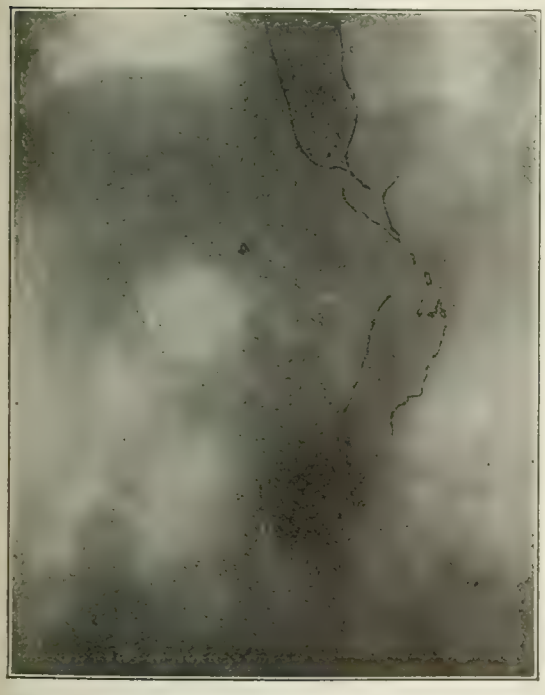


Fig. 2123.—Radiograph of Typical Case of Cardiospasm Engrafted upon a Carcinoma of the Cardia. Note the smooth wall of esophagus with its dilatation proximal to the typically pointed cardia, distal to which is the moth-eaten cardiac end of the stomach through which the bismuth trickles irregularly.

cricoid and progresses downward to the cardia, and radiation of the pain continues down between the shoulders and to the epigastrium. It usually takes one or two minutes for the spasm to relax. Tonic spasm of the esophagus has been noted as a complication of several conditions, chief among which may be mentioned rabies, tetanus, hysteria, and epilepsy. In the two former it is of serious import; in the latter conditions it is usually transitory in nature.

Cardiospasm; Phrenoparalysis. The [illegible] condition was first noted postmortem by Von Ziemssen and Zenker in 1874, who [illegible] observations on cases of idiopathic dilatation of the esophagus, but it was not until 1882 that Mikulicz first attributed it to the presence of [illegible] at the cardia. During the past five years, however,

Fig. 2124.—Radiograph in a Case of Typical Cardiospasm Showing Diffuse Fusiform Dilatation of the Esophagus with Peculiar Characteristic Pointed Distal End.

the recognition of the condition from its clinical picture and its treatment have been so much more frequent and the latter so greatly developed, that several hundred cases have been recorded during this period. The name thus far applied to it, cardiospasm, is probably incorrect owing to the varying ideas as to its etiology which have been promulgated from time to time, as in addition to the above nomenclature we have offered (1) diffuse dilatation of the esophagus without anatomic stenosis (2) fusiform (3) idiopathic (4) uniform diffuse and (5) spontaneous dilatation. Relative to the etiological factor involved a similar dissimilarity of ideas exists, thus (1) primary cardiospasm, (2) primary atony of the esophagus, (3) vagi degeneration, (4) congenital anlage, (5) esophagitis, (6) kinking at the hiatus œsophagi, (7) congenital or acquired asthenia, (8) pressure occlusion from [illegible] of the diaphragmatic crura, and (9) secondary to ulcer or cancer of the stomach (Fig. 2123), gallstones, appendicitis, etc.

The condition may be either acute or chronic. The former is quite frequent, but of transitory nature, and is usually the result of an hyperacidity of the stomach or some corresponding irritant. It resembles the esophageal spasm in general [illegible] other than symptomatic treatment. The chronic form is, however, productive of pathological changes in the esophagus and eventually causes a diffuse dilatation usually extending the entire length of the esophagus; the walls become thickened and a general chronic esophagitis exists. There [illegible]

papillary excrescences, erosions, and scars which from the chronic static irritation to which they are subjected offer an exceptional nidus for the development of cancer.

Symptomatology.—This develops along three distinct lines according to the stage of the condition present and after completion of the pathologic changes a definite practically pathognomonic triad is presented (1) early spasmodic pain, followed after months or years

Fig. 2125. Radiograph in a Case of Typical Cardiospasm showing Diffuse Fusiform Dilatation of the Esophagus, with Peculiar Characteristic Pointed Distal End.

by (2) regurgitation, and this in turn subsequently followed by evidences of (3) retention. The first stage is characterized by retrosternal discomfort and oppression, retroxiphoid cramping, and sensations of choking. The second stage by immediate postprandial regurgitation and a more continuous though frequently milder sensation of tightness in the region of the cardia, with acute exacerbations at times. In the third stage the ingested food is retained longer in the dilated esophagus and is only regurgitated at irregular intervals after eating.

Many variations of this complex picture are present in different cases. The discomfort may be located in the epigastrium, it may radiate to the back or not at all, it may be referred to the left hypochondrium or higher up in the esophagus. The most frequently used expression is that the food seems to "stick behind the breast bone." Again, these subjective sensations may occur entirely independently of food intake. Later the spells of vomiting immediately after eating occur at intervals only and between them no discomfort at all may be experienced. Still later after dilatation has occurred the earlier part of the meal is usually retained, spasmodic cramping has usually disappeared and what is regurgitated is merely from overflow. These patients frequently complain of fluid gushing out on the pillow after they are asleep, an observation which should be very suggestive.

Diagnosis from Objective Examination.—Plummer lays down the following points which should be demonstrated in the diagnosis and study of a case of cardiospasm: (1) the food is regurgitated from the esophagus and not the stomach; (2) the existence and character of obstruction at the cardia; (3) the presence or absence of esophageal dilatation and its shape, size, etc., and (4) the presence or absence of gross lesions in the esophagus or neighboring organs which might excite cardiospasm.

In demonstration of these points he advises that the following measures be resorted to: (1) the various stomach-tube tests, including the methods proposed by Rumpel, Kelling, and Einhorn; (2) passage of a bulbous sound on a whalebone staff; (3) the passage of the Plummer sound; (4) radiographing a bismuth mixture in the dilated esophagus (Fig 2124, 2125, 2126; (5) determinationof the size of the dilatation, Strauss' method, and (6) esophagoscopic examination.

Treatment consists of symptomatic and dietetic measures which need not be detailed; the removal of any extraesophageal irritating factor as gallstones, ulcer or cancer of stomach or appendix, etc., if possible; or dilatation either by hydrostatic or mechanical means, or by open operation directed to the cardia itself. The hydrostatic dilator of Plummer being the most effective and simplest method detail description will be given of it only.

The external construction of this apparatus may be seen in Figs. 2127 to 2130. The description of it and the method of its application by the originator states that it is made by cementing a rubber-dam balloon to one end of a piece of non-elastic rubber tubing in such a manner that the tube just passes through the balloon. A number of holes are so punched in the

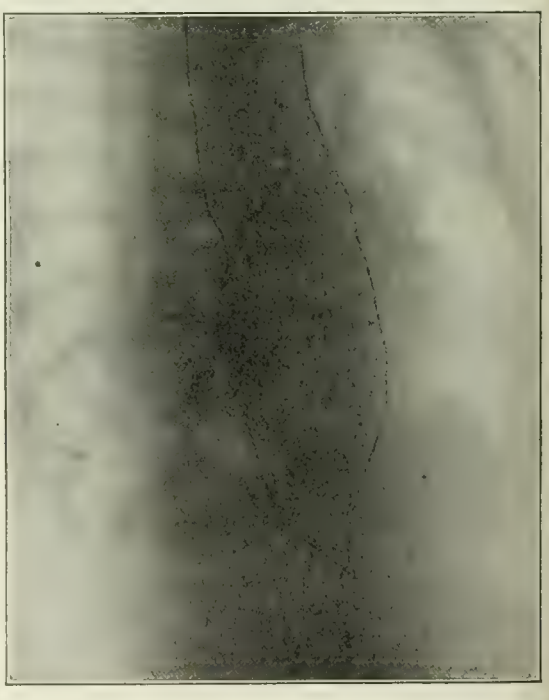


Fig. 2126.—Radiograph of Case of Typical Cardiospasm showing Diffuse Fusiform Dilatation of Esophagus, with Peculiar Characteristic Pointed Distal End.

tubing that its lumen connects with the interior of the balloon. A sausage-shaped silk bag is drawn over the balloon to preserve its shape on distention. Several sizes, ten centimeters long and from twenty millimeters to forty millimeters in diameter are provided. A second rubber balloon is drawn over the instrument to facilitate its introduction. If the dilator is slightly

constricted in its middle third, the tendency for it to slip into the stomach is lessened. Provision is made for removing the staff to prevent its maceration when not in use. The metal tip of the staff is threaded for the set of fenestrated olives used in sounding (Fig. 2128) and for the spiral tip if its use is indicated (Fig. 2129). The dilator is connected by rubber tubing with a water-tap or pump. Into this tubing two hard-rubber T-joints are inserted, one for an altitude gauge or manometer, and the other for a piece of tubing to permit draining the instrument without disconnecting at the tap, and for controlling the pressure (Fig. 2130).

As a preliminary to the use of this hydrostatic dilator, Plummer has perfected a method, earlier suggested by Russell, of having the patient slowly swallow six yards of a silk thread which when threaded through the fenestrated olive acts as a guide. This passes through

Fig. 2127.—The Plummer Hydrostatic Dilator Inflated, and Fenestrated Olive Tip Threaded.

the coils of small intestine becoming engaged in them so that the string cannot be pulled out on being drawn taut. It is advisable to have the patient swallow three yards at first and the remainder after an interval of twelve hours, as snarling may be anticipated if it is all taken at once.

The position of the cardia having been previously accurately determined, the olive is threaded on to the string and the dilator introduced sufficiently far for the cardia to engage the balloon at its middle third. The instrument is held firmly with the right hand, the index-finger resting against the teeth to prevent the dilator being drawn into the stomach. The tap is now opened enough to fill the instrument and deliver a good stream through the tubing for draining the balloon, but not to indicate any pressure. The pressure is now slowly raised by pinching the drainage tube with the fingers of the left hand. This is continued until

Fig. 2128.—Fenestrated Olive for Carrying Thread or Wire Guide. (Plummer.)

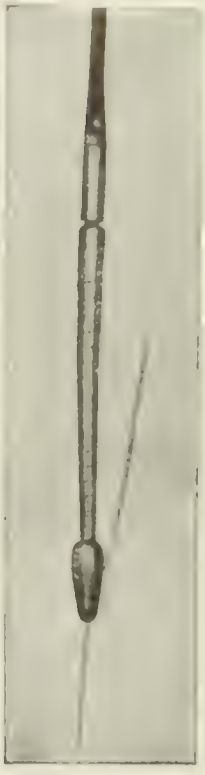


Fig. 2129.—Spiral Tip, used in Connection with the Fenestrated Olive, in Cases of Tortuous Strictures. (Plummer.)

Fig. 2130.—Hydrostatic Dilator showing Arrangement of Tubing and Accessories. (Plummer.)

the gauge registers 575 millimeters which has been found to be sufficient in the great majority of cases and still be within the limits of safety. The number for dilatations averages between one and five. The interval between them should be from four to five days.

The mechanical dilator consisting of parallel blades covered by a rubber-dam and operated by a screw externally, devised by Einhorn, has also been used repeatedly with success but the danger of rupture is much greater than that experienced with the use of Plummer's apparatus and the accuracy of the latter is appreciably greater.

There are, however, certain cases which are resistant to repeated attempts at dilatation, or in which the manipulator may have been unable to enter the cardia; these, then, must be treated by open operation. Three such methods have been advocated and successfully carried out: (1) Mikulicz' method of gastrotomy with introduction of covered forceps through cardia from below and divulsion; (2) Meyer's method of esophagoplication and vagolysis, and (3) Wendel's method of cardioplasty in which he adopted the technique of pyloroplasty by the Heineke-Mikulicz method. Finally palliative gastrostomy may be the only course left owing to the exigencies offered in certain cases.

Stricture of the Esophagus.—This may be a resultant of many diverse factors. Those most continuously met with are: (1) Congenital stenosis, (2) membranous obturation (see the section on congenital malformations), (3) obstructive (see the section on foreign bodies), (4) external pressure (mediastinal tumors), (5) spastic contraction (see the section on motor disturbances), (6) those consequent to cicatricial formation, and (7) those caused by involvement of neoplasms. The latter two will be considered in this section.

Cicatricial stenoses are usually caused by the swallowing of such substances as lye, caustic soda, or acids. Syphilitic hyperplasia is also occasionally found. They are ordinarily symptomatized by an increasing

Fig. 2131.—Abbe's String-saw Operation. Method of using the bougie and string. (Abbe.)

inability to swallow; first solids, later fluids, or the recognition of serious trouble may be delayed until attention is drawn to it by the subjective and objective symptoms consequent to a proximal dilatation or diverticulum which has been formed.

Treatment is either mechanical or operative, the former consisting of the introduction of sounds of increasing diameter. In tortuous strictures the utilization of Plummer's string method and spiral guide may facilitate the introduction of the dilating apparatus which would otherwise be impossible. Many impermeable strictures will relax sufficiently to admit a bougie after a temporary gastrostomy and the esophagus thus put at absolute rest for some time. Koenig's method of dropping silver balls of increasing size onto the stricture which are allowed to remain in over night has resulted in marked relief. The introduction of a Symond's permanent cannula after the method of Mixter has allowed many cases to live in comfort and thus obviated a gastrostomy. The introduction of these catgut bougies through a von Hacker cannula is frequently possible when the passage of a small sound is not.

The entrance of sounds through a stricture from above having been found impossible, several ingenious methods have been evolved which necessitate an opening in the stomach. The most practical and the one which seems to have given the best results is the method of Abbe, viz., retrograde dilatation through gastrostomy. A gastrostomy is done and a fine whalebone bougie introduced from below upward until it protrudes from the mouth or through a previously made external incision above the stricture. A stout thread or piece of braided silk is then drawn through and after making the stricture tense by introducing a conical bougie (Figs. 2131 and 2132), the

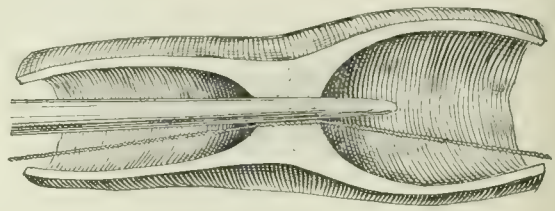


Fig. 2132.—Abbe's String-saw Operation. String dividing the esophageal stricture kept tense by bougie. (Abbe.)

string is pulled up and down sawing through the stricture, and as the cicatricial tissue gives way the bougie may be introduced further and further until it slips through; subsequent passage weekly of a full-sized bougie effects a prompt cure. Ochsner also obtained good results from drawing a rubber tube caught in the middle and drawn out taut to diminish its diameter to the caliber of the stricture aperture and pulling it up through the stricture, employing successively increasing sizes of tubing as the progressive dilatation of the stricture allows. The Hacker-Socin-Mikulicz method is founded on the same principle except single tubes are used in increasing diameter, which are allowed to remain from one to two weeks before the next size larger is introduced. Eiselsberg employs a conical rubber tube in the same way. It is possibly more convenient to handle this after it has once been introduced and tolerance established.

Internal esophagotomy with an instrument of the Maisonneuve type has practically been discontinued owing to the dangers involved and the lack of control of the depth of the incision or its exact location, and the frequent hemorrhage following. Any cutting should be done under direct inspection through an esophagoscope. The use of electrolysis is of questionable value.

Three types of open operation have been practised successfully in those cases in which the stricture resisted all of the above detailed methods to enter and dilate it: (1) external esophagotomy or esophagectomy in the cervical region, (2) thoracic mediastinotomy with secondary esophagectomy, and (3) esophagogastric anastomosis with low esophagectomy under differential pressure. (See the section on operative methods.)

Strictures of the esophagus by neoplasms may be either benign or malignant in character. Bening tumors are rare and but infrequently diagnosed. They consist chiefly of cystomata, caused by retention in the mucous follicles, papillomata, fibromata, myxomata, myomata, lipomata, and adenomata. The diagnosis is usually possible only by the use of the esophagoscope, although occasionally pedunculated tumors have been forced up into the pharynx and thus recognized. Papillomata may occur anywhere along the tract of the gullet. They are noted most frequently in elderly people and are frequently multiple. These three observations hold good as a whole for all

other benign growths. Their symptomatology is quite variable causing in some instances practically no trouble whatever, in others with seemingly less involvement severe attacks of dysphagia and even dyspnea. Their treatment consists in removal or puncture in the case of cystic formation. When the growth is pedunculated it can conveniently be cut through an esophagoscope, or if it can be delivered into the pharynx it may be grasped and either cauterized or snared off. External esophagotomy may be found necessary, or even gastrotomy, if there is great emaciation. In instances of asphyxia tracheotomy may become essential.

Malignant tumors involving the esophagus consist of two varieties, sarcomata, and carcinomata. The former are very rare occurring as a rule in old people. They may be either primary or secondary, the former occurring at the introitus esophagi, although they have been noted at the constriction opposite the tracheal bifurcation. They are generally of the round-celled variety. Symptoms produced by this growth are slow in developing and no treatment other than the exhibition of Coley's mixed toxins has been attempted. It is doubtful if surgical removal is indicated, if the examiner is sure of the diagnosis.

Carcinoma is a condition affecting the esophagus more frequently than any other pathological alteration, its incidence has been placed at eighty per cent. The seat of involvement is usually in the region of the cardia (seventy per cent.), next at the introitus (fifteen per cent.) and the thoracic segment is involved in approximately fifteen per cent. of the cases. It occurs more frequently in men than in women, approximately in the ratio of 3 to 1. The majority of cases being found between the ages of forty-five and fifty-five, indeed, the fortieth to the forty-fifth year, seems to divide esophageal cases into two groups. In the earlier period carcinoma is very rare, while in the latter group it is by far the most common affection. It frequently complicates a preexisting benign condition, such as tubercular or simple ulceration, cicatricial strictures, diverticula, chronic esophagitis, or cardiospasm. Stress has also been laid on the frequency of its occurrence in cases subjected to continued mechanical irritation, and in those addicted to tobacco and alcohol. Chemical and thermic factors should also be considered.

The pathological picture in its entirety consists of infiltration, growth, obstruction, destruction, ulceration, and contraction. The carcinoma may be either primary or secondary by contiguity, metastasis from other foci does not appear to occur in this organ, autoimplantation has, however, been noted. The character of the typical esophageal growth consists usually of epitheliomatous proliferation. Of rarer occurrence is cancer of the glandular and colloid type. The progress of extension is peculiarly slow in esophageal involvement and frequently limited to one wall for a long period of time. Metastases are also slow in taking place.

Symptoms occur early as a rule, unfortunately they are belittled in most instances until extensive involvement has occurred. Probably the earliest in occurrence is the change in character of the deglutition murmur, thus, in the involvement high up the early or squirting sound may be markedly inhibited, if in the thoracic segment the second or squeezing murmur which normally occurs seven seconds after swallowing is more or less delayed, and in cardial carcinoma this sound may not only be altered in character, but be entirely absent. These phenomena are, however, seldom noted until dysphagia which is the cardinal symptom of the disease has been ushered in. This symptom is invariably progressive in character, first being noticed after ingestion of solid food, later even liquids cause marked discomfort, although in many instances when ulceration and sloughing take place there may be a prolonged period of marked amelioration, or even a practical disappearance of the dysphagia. As a result of insufficient nutrition, loss of strength and flesh, cachexia emaciation become progressively more pronounced. Anorexia, nausea, vomiting, regurgitation, cough, dysphonia, excessive thirst, and [illegible] complete the general picture. Darting pains radiating to the back, shoulders and neck indicate extension into the nerve trunks. A peculiar bursting or breaking sensation is frequently complained of in some late cases and may be attributed to [illegible] involvement.

Diagnosis.—The subjective history and general objective findings are of the utmost importance, but pathological examination of tissue removed and ocular demonstration of the growth itself should be obtained a certain diagnosis should be made. The location of the stricture should be ascertained and the character of the walls at this point be determined. The methods at our disposal for accomplishing this

Fig. 2133.—Radiograph of Carcinomatous Strictures of the Thoracic Esophagus, with Proximal Dilatation. Note the irregular ragged or moth-eaten edges, or even [illegible]

are afforded by the use of esophagoscopy, sounding and radiography (Fig. 2133) the technique of which is elsewhere described.

Treatment of carcinoma of the esophagus may be either medicinal, mechanical, palliative, or radical. Therapeutic treatment has until lately had merely a symptomatic basis for its exhibition and consists merely of the application of opiates, cocaine, lavage with salt, borax, soda, or a one to four per cent. silver nitrate solution. For the relief of the dysphagia a combination such as the following will be found most useful, dioninæ and codeinæ hydrochloridi āā gr. iss, cocainæ hydrochloridi gr. iv, ammonii valeratis and aqua amygdalæ amaræ āā 5ii. Sig. Fifteen drops three or four times a day. Atropine and potassium iodide have also been given. Temporary results have lately been claimed by the introduction of radium to the site of stricture, using 100 milligrams encased in a lead and gold [illegible] and allowed to remain in apposition to the growth from

six to eight hours at varying intervals of time, combined however with dilatation of the stricture. The injection of various substances which are claimed to have a particular affinity for cancer cells and which destroy them have as yet not been perfected to a degree that warrants their recitation.

Mechanical treatment consists of dilatation of the stricture by one of the methods previously described. Probably the most efficacious and certainly the safest procedure is that of employing the string guide method of Plummer with the fenestrated olive bougie. Dilatation may be safely carried at the first sitting to a No. 35 or 40 F. Cutting through the protruding growth by the Abbe string method and subsequent dilation has also given good results. A marked relief from the dysphagia is thus frequently afforded and moderate comfort obtained for many months or even longer periods.

Palliative treatment should emaciation occur very rapidly or the general condition of the patient be so poor that instrumentation is contraindicated, or conditions be such that a short prolongation of life desired, should consist of a simple gastrotomy. The results obtained from such operative intervention are questionable and as a rule unsatisfactory.

Radical operative interference in cases of carcinoma of the esophagus especially in involvement of the cardial portion, has made extraordinary progress since the introduction of the differential pressure cabinet introduced by Sauerbruch and the method of intratracheal insufflation anesthesia, as elaborated by Meltzer. Operations which have been performed successfully consist, according to the location of the tumor, of cervical resection, resection of the thoracic segment through a posterior thoracic mediastinotomy, and resection of the cardial segment with a subsequent esophago-gastroanastomosis, or a dislocation of the jejunum under the skin of the thorax, or by resection of the greater curvature of the stomach and a dislocation of it under the skin of the thorax. These procedures will be considered under the description of operative methods.

Diverticula of the Esophagus.—Several classes of this condition are recognized and may be considered either from their etiologic or from their anatomic and clinical aspect. The former group is therefore divided into (1) traction, (2) pressure or pulsion and (3) traction—pressure diverticula, according to the processes involved in their formation. The second class comprises four subdivisions which are self-explanatory (1) pharyngeal, (2) pharyngoesophageal, (3) midthoracic, and (4) infrabifurcal diverticula or those situated below the level of the bifurcation of the trachea. This type is particularly infrequent in occurrence, while the pharyngoesophageal type is the most common.

Symptoms are those of a gradually increasing stenosis, interference with swallowing being slight at first, merely a sense of obstruction being complained of. This is followed by irregular regurgitation of undigested and non-acid material. The progressive stenosis is entirely dependent upon the increase in size of the sac which causes pressure upon and subsequent occlusion of the esophagus. Pain after eating is frequently complained of due to distention of the sac and pressure exerted on the adjacent structures by it. Immediate relief is afforded by regurgitation of the contents. Progressive emaciation and death from inanition ensues if the condition is not recognized and relieved.

Diagnosis is as a rule relatively simple. In the most frequent type of pharyngoesophageal dilatations, the tumor usually lies on the left side of the neck and is frequently mistaken for the enlarged left lobe of the thyroid. Pressure upon it causes its contents to swell up into the mouth and this affords the examiner a pathognomonic phenomenon. Dysphonia, dyspnea, and even asphyxia may occur, while many complain of an irritative cough. A radiograph after administering a bismuth meal shows with great definiteness not only the presence but the situation, size, and direction of the diverticulum. (Figs. 2134, 2135, 2136, and 2137).

Fig. 2134.—Radiograph of Diverticulum of Esophagus Injected with Bismuth. (Mayo.)

Diagnosis of the more deeply situated dilatations is more difficult but of extreme importance particularly its differentiation from dilatation resultant to cardiospasm. The most exact evidence may be obtained here also by the use of the radiograph. Of confirmatory nature the use of Strauss' volume measure, or Rumpel's double sound and esophagoscopy may be

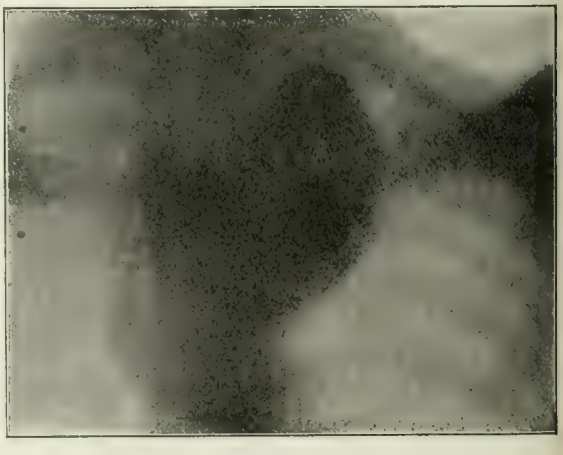


Fig. 2135.—Radiograph of Diverticulum of Esophagus Injected with Bismuth. (Mayo.)

employed, and of particular value the use of the Plummer string guide method of sounding. The information thus obtainable is well shown in Figs. 2038 and 2039. This will be found of particular advantage in greatly emaciated cases in whom an operation in such an enfeebled condition would be dangerous, as a stomach

tube may be threaded over the string guide and food thus given without the necessity of a preliminary gastrostomy.

Treatment may be palliative or radical. The former consisting of sounding which has given moderate

Fig. 2136.—Radiograph of Diverticulum of the Esophagus Injected with Bismuth. (Mayo.)

relief in a few instances and symptomatic measures as suitable diet, position, and irrigation of the diverticulum which have held the condition in check for many years in some cases.

Operative Method.—Incision along the inner margin of the left sternomastoid muscle which is drawn

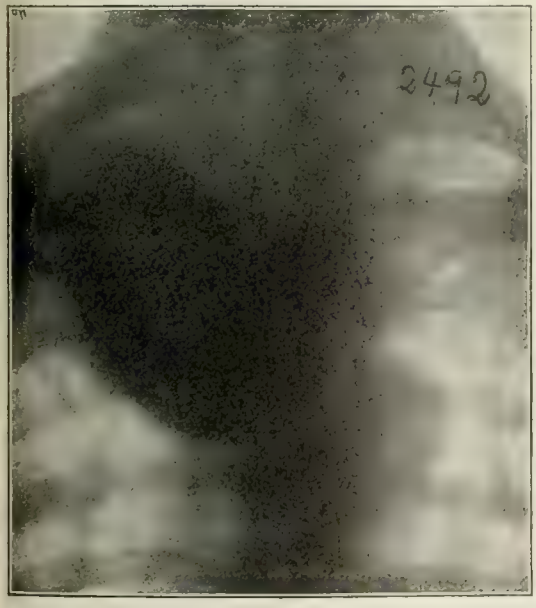


Fig. 2137.—Radiograph of Diverticulum of Esophagus Injected with Bismuth. (Mayo.)

outward, while the anterior sternal neck muscles are tracted inward. The lobe of the thyroid is elevated and the lateral thyroid vein ligated and cut, care must be exercised to avoid the recurrent [illegible]. Should difficulty arise owing to [illegible] nize the sac, an urethral sound [illegible] through the mouth into the pharynx [illegible] to elevate the sac into the wound. [illegible] and its interior examined. It is then [illegible] the edges of the wound in the esophageal wall inverted by a continuous mattress suture, a reinforcing Cushing parallel suture of fine gut is then applied. A temporary rubber tissue drain should be inserted. It is wise to empty the sac before the anesthesia is begun. The after-treatment consists of enteroclysis (Murphy) and feeding twice daily by means of a small stomach tube. Infrequent sips of hot water may be allowed on the second day. Mayo reports six operative cures, no mortalities and but two fistulæ by this method. The writer has found the use of a duodenal feeding tube ideal for the conveyance of liquid nourishment by any lesion of the esophagus or stomach, and its use will be found particularly applicable after the above operation.

Fig. 2138.—Sound Pocketed in a Low Diverticulum, but Threaded over Guide String. (Plummer.)

Fig. 2139.—[illegible] how the Depth of the Diverticulum may be Accurately Ascertained by [illegible] the String being [illegible] out of the Diverticulum and over the Lip into the Esophagus. (Plummer.)

In cases of small diverticula the method of Girard of inverting the diverticulum and allowing it to atrophy may be employed. Danger of stenosis in larger dilatations precludes this procedure.

Operative Methods. *Cervical esophagotomy* may be indicated in the removal of foreign bodies, extirpation of diverticula, division of strictures and for facilitating the sawing through of strictures lower down. The steps in the operation are practically those just described for the extirpation of pharyngoesophageal diverticula.

Cervical mediastinotomy has been performed several times by going down in the retroesophageal space to the median side of the large vessels, or between the heads of the sternocleidomastoid muscles from the clavicle on the right side, between the carotid and the jugular vein, or on the left side to the outer side of these two vessels, and phlegmons of the thorax thus drained.

Cervical esophagostomy is performed in a similar manner except the esophageal mucosa is sutured externally to the skin.

Cervical resection of esophagus (*esophagectomy*) is indicated in certain cases of impermeable stricture and small carcinomata high up. Its mortality is high. The technique consists of the steps indicated for esophagotomy. The esophagus is dislocated with a blunt dissector, and if the excised portion is not too long, the proximal and distal ends may be directly connected by a circular suture. Otherwise, both are brought out to the skin and subsequently joined by a skin plasty. A temporary gastrostomy or tracheotomy may be indicated by the local conditions. The after-treatment may necessitate a gastrostomy. The duodenal feeding tube is an essential adjunct. The dressings must be changed frequently and the drainage must be thorough.

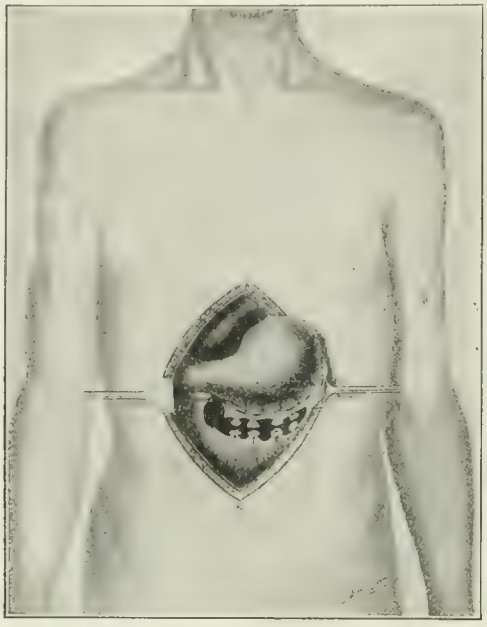


Fig. 2140.—Showing Double Ligation and Division of Great Omentum up to Reflection of Left Inferior Epiploic Artery onto the Stomach, also Double Ligation and Division of Right Inferior Epiploic artery, and Exposure of Great Curvature of the Stomach. (Meyer.)

Dorsal Mediastinotomy, Posterior Thoracic Esophagotomy and *Resection of the Thoracic Segment of the Esophagus* (*Esophagectomy*, Torek).—Various methods of transthoracic approach to the esophagus have been devised chiefly for the removal or impacted foreign bodies. All such operations have proven formidable not because of the difficulty of the operation *per se*, but owing to the frequency of resultant mediastinitis, this may to a great measure be mitigated by employing duodenal alimentation in the postoperative treatment. For greater difficulties are offered, however, in resecting the thoracic portion of the esophagus for carcinoma. Torek has achieved success by making an incision through the whole length of the seventh left intercostal space, from the posterior end of which the incision was continued upward, cutting through the seventh, sixth, and fourth ribs at their angles. This is much simpler than the previously employed methods of taking off the scapula, or resecting several adjacent ribs, or of going in through two separate intercostal spaces, as it is more quickly executed and gives a better exposure than any of the other methods of access. To reach the parts behind the arch of the aorta a number of its thoracic branches were divided and the aorta lifted forward. The proximal stump of the esophagus were dissected free and transposed extrathoracically through an incision at the anterior

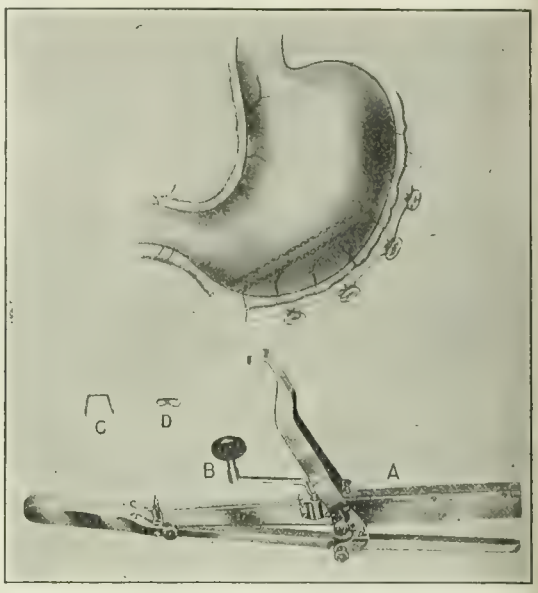


Fig. 2141.—Method of Application of Hueltl's Wire-stitching Instrument to Stomach, showing Double Row of Through-and-through Staples in Place. The lower illustration A shows the instrument. B shows the crank which when turned five times after closing the clamp, drives all the staples (C) through all intervening tissues and clamps them (D) on the opposite side. (Meyer.)

border of the left sternocleidomastoid muscle, thus obviating any postoperative intrathoracic leakage which had previously been the cause of the great majority of deaths.

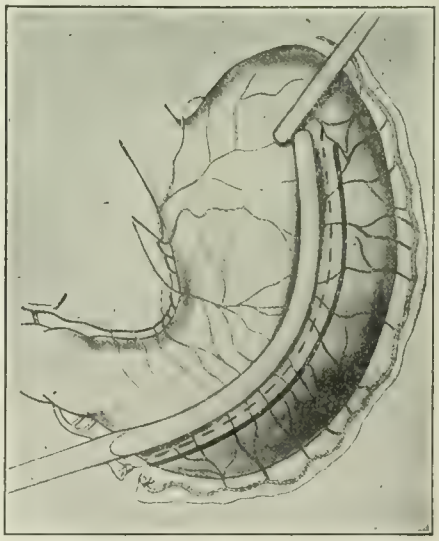


Fig. 2142.—Showing Application of Long Clamps placed Parallel to the Greater Curvature in Case Hueltl's Instrument is not used. (Meyer.)

Extrathoracic Inferior Esophagoplasty.—Jianu's Operation is applicable to form a new tube, one end connected with the gastric fundus, the other situated high up on the chest wall. It is described by Meyer as

consisting of a median abdominal incision above the umbilicus, pulling forward of stomach, double ligation and division of major omentum from a place about two inches from the pylorus up to the region where the left inferior epiploic artery turns onto the stomach. Ligation of right inferior epiploic artery next to the first omental stump, completely baring the stomach wall (Fig. 2140). A mattress suture is run from here

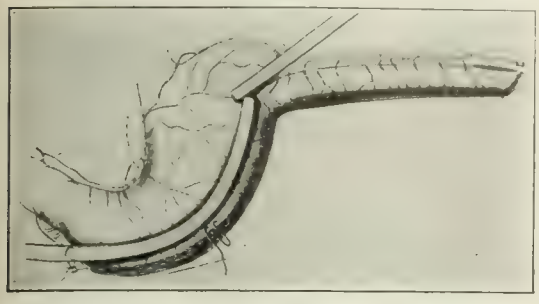


Fig. 2143.—Illustrates the Clamps Still in Place and the Greater Curvature formed into a Tube by Connell's Sutures, Reinforced by the Cushing Mattress. (Meyer.)

through the entire thickness of the stomach about one and one-half inches distant from and parallel with the greater curvature Hueltl's wire stitching instrument is applied in a similar position (Fig. 2141) the stomach having been lifted up in order to have the contents run toward the lesser curvature. The stomach is then divided between the two rows of staples or between the line of mattress sutures and a

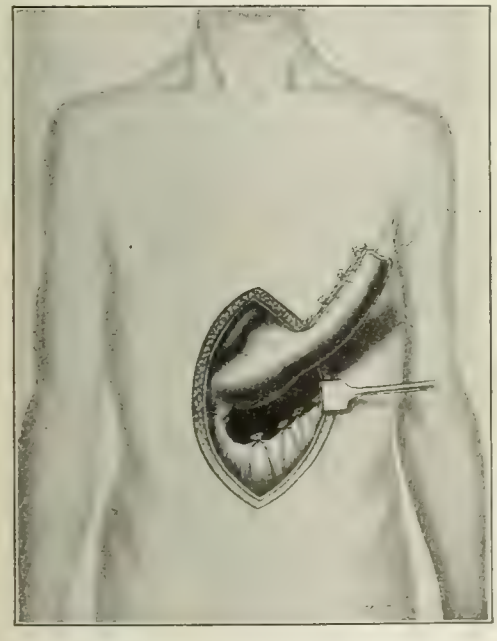


Fig. 2144.—Inversion of the End of the Jianu Tube with the Ends of the Sutures left long. (Meyer.)

clamp, if Hueltl's clamp is not used, and what was formerly the greater curvature is turned up and formed into a tube by a Connell's suture (Figs. 2142 and 2143); a Cushing mattress suture inverts the first row, the end of the tube is temporarily inverted by three sutures, leaving the ends long (Fig. 2144). Stomach turned so that the base of Jianu tube corresponds to upper angle of abdominal wound where it is secured by a few sutures. Closure of lower half of abdominal wound. New formed tube is then sutured to the external surface of chest to left of sternum and a horizontal incision made at upper level of tube, skin of

Fig. 2145.—Showing the Method of Drawing the Tube up under the Skin of the Thorax. The undermined part of the thorax should be quite broad. All projecting sutures shown in greater but not the gut. (Meyer.)

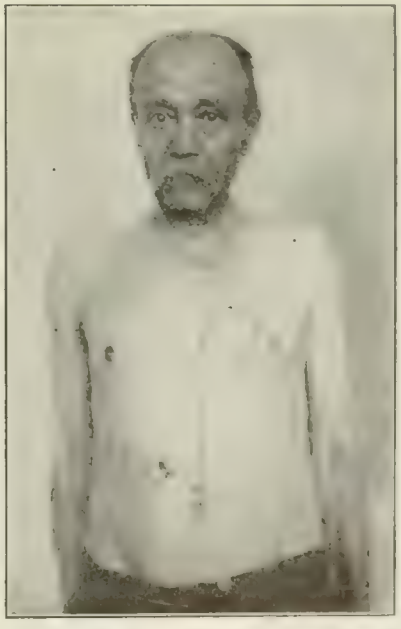


Fig. 2146.—Closing the Abdominal Incision, Fixing and Suturing the End of the New Tube by its Mucosa to the Skin of the Thorax. (Meyer.)

thorax thoroughly undermined and tube pulled up with long forceps which grasp the ends of inverting sutures (Fig. 2145); mucosa then sutured to skin, closure of remainder of abdominal incision (Fig. 2146).

Intrathoracic Inferior Esophagoplasty.—Meyer's Operation. In this the originator utilizes the entire technique of Jianu, but instead of transposing the tube under the skin, pulls it up into the pleural cavity

Fig. 2147.—Meyer's Method. Inverted tip of Jianu tube cut off and sutured end to end with proximal end of severed esophagus, intrathoracically. The ligated greater omentum always toward the right. (Meyer.)

through a hole in the diaphragm and anastomoses it directly to the proximal stump of the esophagus thus replacing the excised portion and reëstablishing normal relations (Fig. 2147).

Inferior Extrathoracic Esophagoplasty.—Von Finck Method. Here is utilized the stomach and first

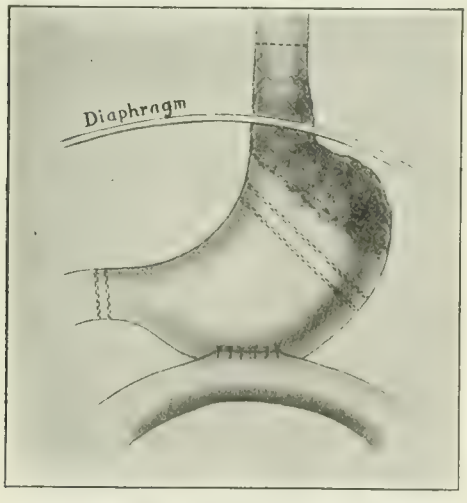


Fig. 2148.—Showing Situation of Cardial Carcinoma with Gastric Extension of such Degree as to preclude the Formation of the Jianu Tube. (Meyer.)

portion of the duodenum, and is applicable to those cancers of the cardia which extend downward involving the cardial fundus (Fig. 2148) and thus preclude the formation of a Jianu tube. Technique: The duodenum is doubly ligated and divided at the junction of the horizontal and descending portions (Fig. 2149). The whole viscus is then transposed under the skin of the thorax through a hole made in the abdominal wall, after resection of a portion of the left ninth rib

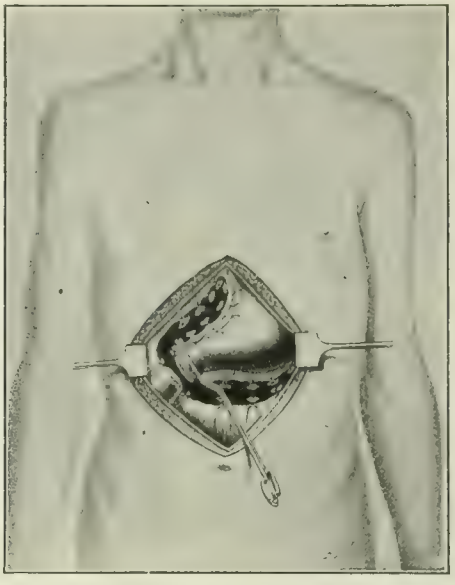


Fig. 2149.—Primary Step in von Finck's Operation. Division of duodenum after freeing greater and lesser curvatures. (Meyer.)

(Fig. 2150), a posterior gastroenterostomy closing the first stage of the operation. At the second sitting the cancer is excised and distal portion of the stomach closed, the proximal stump of the esophagus is then

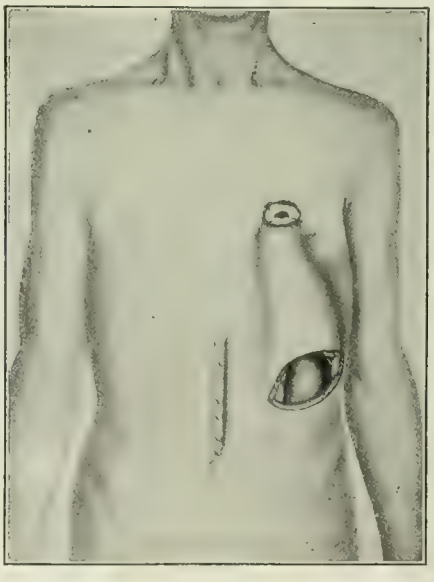


Fig. 2150.—Showing the Transposed Stomach and First Portion of Duodenum under the Skin of the Thorax after Resection of the Left Ninth Rib. (Meyer.)

transposed extrathoracically and anastomosed to the presenting end of the duodenum.

Inferior Intrathoracic Esophagoplasty.—Ach Method whereby the distal end of the esophagus and the

mobilized stomach are utilized to fill in the defect resultant to removal of the middle portion of the gullet.

Inferior Extrathoracic Esophagoplasty.—Kelling-Vulliet Method. The transverse colon is totally excluded and transposed extrathoracically (Fig. 2151).

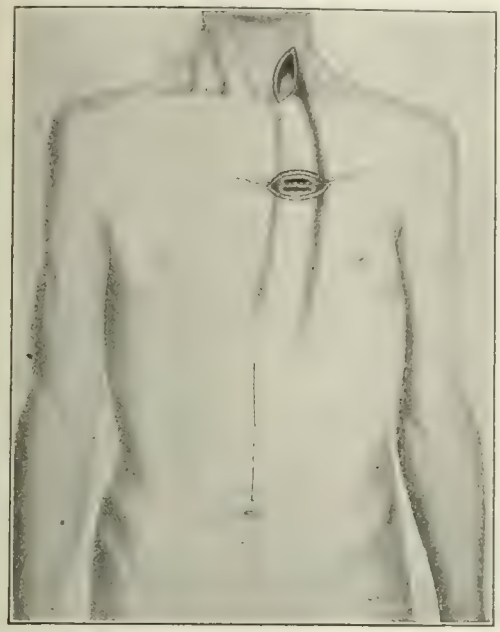


Fig. 2151.—Showing the Kelling-Vulliet Method of Transposing the Transverse Colon Extrathoracically. (Meyer.)

Inferior Extrathoracic Esophagoplasty.—Wullstein-Roux Method. Is performed by a total exclusion of a coil of jejunum, which however necessitates several stages (Fig. 2152).

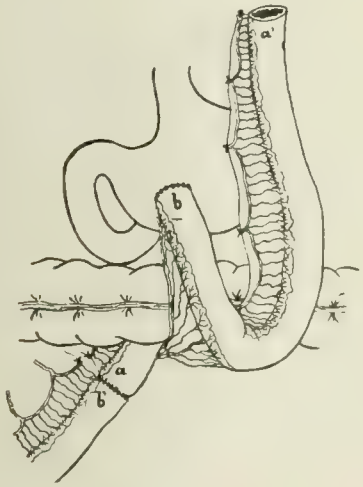


Fig. 2152.—Wullstein-Roux Method of Total Exclusion of a Coil of Jejunum and its Transposition Extrathoracically. (Rovsing.)

Esophagoenteric junction by skin plasty was first shown to be feasible by Bircher, and was later elaborated by Lexer. Technique: Horizontal skin incision at level of cricoid cartilage and a second one parallel to it below costal arch or at level of transposed tube of intestine or stomach; their outer ends [illegible] perpendicular incision and flap loosened [illegible] sutured to the median border [illegible] of finger's size, lined with epidermis throughout; a double bridge flap moved inwardly from either side of the outer portion of the skin of [illegible] tube; the lower end is then united with the intestine or stomach and the upper end with the oral end of the esophagus.

Fig. 2153.—Method of Anastomosis between the Transposed Cervical or Thoracic Segment of the Esophagus. (Meyer.)

The cervical or thoracic esophagus may be evulsed from the body and transposed under the skin of the thorax and united with the presenting viscus from below (Fig. 2153), or the two ends may be connected by means of rubber tubing (Gluck, Perthes.)

James Taft Pilcher

Esperanza Mineral Springs.—Yates County, New York.

Post-office.—Pen Yan.

Access.—By steamers on Lake Keuka or by a trolley line between Pen Yan, which is six miles distant in one direction, and Branchport, one mile distant in the other.

The springs are located at the head of the west branch of Lake Keuka, one of the most charming and picturesque of the many series of lakes which give the name of the lake section to this part of central New York. Lake Keuka is 700 feet above the ocean level, and within a mile of the springs an elevation of 1,100 feet higher may be reached. This is the great grape-producing section of New York, and the country about the lake is dotted on every hand with vineyards. There is a fine beach. Lovely walks, drives, and bicycle paths abound on all sides. The largest of the springs flows about 1,000 gallons hourly. The water has a temperature of 51° F. A qualitative analysis shows the following ingredients: Calcium carbonate, calcium sulphate, calcium phosphate, calcium chloride, magnesium chloride, magnesium carbonate, magnesium [illegible] (trace), sulphureted hydrogen gas, and carbonic acid gas.

The water, when first taken from the spring, has both the taste and the smell of sulphur, but this disappears after a few hours, and the water becomes very palatable. There is no hotel at the springs, though there are many within easy reach. Lake Keuka is well supplied not only with hotels, but with cottages, steam yachts, sail-boats, and various forms of amusement. No systematic effort has so far been made to put the Esperanza Spring waters on the market, although large quantities have already been sold. EMMA E. WALKER.

Essence.—This term seems to have no definite and generally accepted meaning. As ordinarily used, it is supposed to represent an alcoholic solution of a volatile oil, or an alcoholic preparation of some aromatic principle. Fortunately, both the United States Pharmacopœia and the British Pharmacopœia have abolished the term from their official preparations. The National Formulary lists four essences, one of which (*essence of ginger*) is a liquor or solution, one (*essence of lemon*) is a spirit, and one (compound *essence of vanillin*), is a compound tincture. The remaining one, *essence of pepsin*, contains: Pepsin 22.5, rennin 16.5, lactic acid 2, tincture of sweet orange peel 10, glycerin 125, alcohol 50, syrup 65, white wine 365, purified talc 15, and water to 1000. The dose is 2 drams (8 c.c.). R. J. E. SCOTT.

Esthesiometers.—The word esthesiometer is derived from the Greek *αἰσθάνομαι*, I perceive, *αἴσθησις*, perception, sensation, and *μέτρον*, a measure; thus meaning literally a measure of sensation; and it is used to denote an instrument which measures that form of sensation known as tactile sensibility (*Tastsinn* in German).

Touch or tactile sensibility is resolvable into at least two elements, light touch—epicritic sensibility of Head, and pressure touch.

Esthesiometers, properly so called, are instruments for testing the sense of touch, the pressure touch threshold, or the perception of roughness, etc. The first one used, one which under slight modifications still retains its place, is that of E. H. Weber, who, in 1829, appears to have published his first account of his investigations in regard to the sense of touch discrimination. The instrument had probably, however, been for some time in use at that date, for in 1846 he refers to its use twenty years ago. It consisted simply of a pair of compasses with cylindrical arms, the points of which were so ground down that their ends had a diameter of one-third line, so that they should produce simply a sensation of touch and should avoid any sensation of pain. To use this instrument it was only necessary to place the two points upon the skin of the person to be examined, care being taken at the same time that he should not see whether both points or only one touched his skin, and by examination to find out at what distance from each other it was necessary that the points should be in order that they should be distinctly felt as separate. For in any portion of the skin two distinct points, if placed near enough together, will be felt as only one. Light touch may be determined by the use of cotton wool on both hairless or hair-clad parts. The threshold of light touch may also be determined by the use of von Frey's hairs. Pressure touch is determined by a pressure esthesiometer.

Weber found that the sense of touch discrimination, *i.e.* the ability to discriminate simultaneous contacts, varied much in healthy individuals in different parts of the body, and varied also somewhat, especially on the limbs, according to the direction in which the points were placed, whether longitudinally, obliquely, or transversely. His figures and those of Valentin for the normal distance between two points, which can be distinguished as such in the various parts of the body, are as follows:

TABLE OF VARIATIONS OF THE SENSE OF LOCALITY IN DIFFERENT PORTIONS OF THE SKIN (WEBER AND VALENTIN).

(The subjoined table gives the mean minimum distances (in Paris lines—2.256 mm.) for different parts of the body between the points of the esthesiometer at which two impressions can be distinguished when the points are applied simultaneously. The first column gives the results of the experiments of Weber, the second of those of Valentin, while the third column (also from Valentin) gives the relative obtuseness of each portion of the body, the most delicate part, the tip of the tongue, being taken as the unit of measurement.)

Part of surface.	Weber.	Valentin.	
		Mean.	Relative obtuseness.
Tip of tongue	0 50	0 483	1.000
Palmar surface, third phalanx of forefinger	1 00	0.603	1.248
Palmar surface, third phalanx of middle finger	1 00	0 706	1.462
Palmar surface, third phalanx of ring finger.	1 00	0.723	1.497
Palmar surface, third phalanx of thumb.	1 00	0.725	1.501
Palmar surface, third phalanx of little finger.	1 00	0.733	1.518
Red surface of under lip	2 00	1.500	3.106
Red surface of upper lip	2 00	1.520	3.147
Palmar surface, second phalanges of fingers.	2.00	1.558	3.226
Palmar surface, first phalanges of fingers	...	1.650	3.416
Dorsum of tongue (one inch from tip, Weber)	4 00	1 916	3.967
Dorsal surface, third phalanx of finger	3 00	2.125	4.400
Portion of lips not red	4 00	2 208	4.572
Tip of nose	3.00	2 250	4.658
Edge of tongue, one inch from t p	...	2.478	5.130
Palmar surface of the metacarpus (capitula ossium).	3.00	2.625	5.434
Lateral surface of dorsum of tongue	....	2 500	5.176
End of great toe (plantar side of last joint, Weber).	5.00	3.250	6.729
Metacarpal joint of thumb	4 00	3.333	6.901
External surface of eyelids	5.00	3.833	7.936
Palm of hand	5 00	3 833	7.936
Dorsal surface of second phalanx of thumb.	5 00	3 893	8 060
Dorsal surface of second phalanx of forefinger	5.00	3 893	8 060
Dorsal surface of second phalanx of middle finger.	5.00	3.900	8.075
Dorsal surface of second phalanx of little finger.	5 00	3.943	8.163
Dorsal surface of second phalanx of ring finger.	5.00	3.971	8.221
Center of hard palate	6 00	4.042	8.369
Mucous membrane of lips near gums	9 00	4 125	8.540
Skin of cheek over buccinator	5 00	4 541	9.402
Skin of cheek over anterior part of malar bone	7 00	4 620	9.565
Dorsal surface, first phalanx of finger.	7 00	4.917	10.180
Prepuce		5 100	10.559
Dorsal surface of heads of metacarpal bones.	8 00	5 250	10 869
Cheek, over posterior part of malar bone	10.00	5.286	10.944
Plantar surface of first metatarsal	7 00	5.875	12.164
Lower part of forehead	10 00	6.000	12.422
Back of hand	14 00	6 966	14.423
Lower part of hairy scalp in occipital region.	12.00	8.292	17.168
Surface of throat beneath lower jaw	15 00	8.292	17.168
Back of heel	10.00	9.000	18.634
Pubes		9 200	19.048
Crown of head	15 00	9.583	19.840
Patella and surrounding parts	16.00	10.208	21.135
Areola around nipple		12.066	24.982
Dorsum of foot, near toes	18.00	12.525	25.932
Axilla	...	13.000	26.915
Skin of forearm (upper and lower extremities of forearm, Weber).	18.00	13.292	27.520
Back of neck (over spinal column, Weber).	24.00	13.292	27.520
Upper and lower extremities of lower leg	18.00	13.708	28.381
Penis	18 00	13.850	28.675
Acromion and upper part of arm	18.00	13.886	28.708
Sacral region	18.00	14.958	30.969
Sternum	20.00	15.875	32.867
Gluteal region	18.00	16.625	34.420
Middle of arm	30.00	17.083	35.368
Middle of thigh	30.00	17.633	36.507
Spine near middle of cervical vertebræ	30.00	18.542	38.389
Spine near fifth dorsal vertebra	24 00	19.000	39.337
Lower part of thorax, and over lumbar vertebræ.	21.00	19.912	41.225
Middle of dorsal vertebræ	30.00	24.208	50.120

Foster gives the following figures in millimeters obtained by the use of a pair of compasses (a Paris line equals 2.256 millimeters):

Tip of tongue	1.1 mm.
Palmar surface of terminal phalanx of finger	2.2 mm.
Palmar surface of second phalanx of finger	4.4 mm.
Tip of nose	6.6 mm.
White part of lips	8.8 mm.
Back of second phalanx of finger	11.1 mm.
Skin over malar bone	15.4 mm.
Back of hand	29.8 mm.
Forearm	39.6 mm.
Sternum	44.0 mm.
Back	66.0 mm.

In 1858 Sieveking published the account of his esthesiometer in the *British and Foreign Medico-Chirurgical Review*. The principle is the same as that of Weber's, but the form is somewhat altered. Instead of using the common compasses Sieveking has made his instrument in the form of the beam compass used by mechanics; that is to say, of a solid graduated bar of metal, which terminates at one end in point running at right angles to the bar, while on the bar slides another point of horn or ivory, which can be fixed at any desired distance from the first by means of a screw on top. A modification of Sieveking's esthesiometer wrs made by Brown-Séquard, who made both the bar itself and the points lighter and did away with the screw at the top of the movable point. In his instrument the points are of steel, and there is a roughened prominence on the side of the second point to enable it to be readily moved by the finger or thumb (see Fig. 2154). Nearly all the esthesiometers

Fig. 2154.—Brown-Séquard's Esthesiometer (reduced in size).

at present used are modifications of these two forms. Hammond's convenient little instrument is a modification of Weber's, consisting essentially in allowing the index bar to swing on a rivet fastened to one arm of the compass, the bar, while in use, being held by a catch on the other arm, in which it slides freely. When not in use it can be lifted from the catch and swings into approximation with the arm to which it is fastened, so that the whole instrument, when closed, occupies but little space and can readily be carried in the pocket. Carroll's instrument is simply a compass, each arm of which ends in two points, one blunt and one sharp, either of which can be used as desired; while Vance's is an arrangement of compass with flattened arms, which shuts up in a case like a penknife. Gordon Holmes has constructed one of the simplest and most practical types. It consists of a short-limbed flat calipers with blunt turned ends, distances being marked on the sides.

The ability to discriminate two points may be tested in two ways: The points may be applied simultaneously or in succession. In the latter method one point of a compass is brought in contact with the skin and then while in contact the second point is rapidly placed upon the skin. In testing for cerebral lesions this second method often gives valuable information.

The older experiments of Weber, Vierordt, and others were directed largely to an intellectual appreciation of the distances subtended by the compass points. The more recent work of Head is more directly applicable to the discriminating when one or two points are touched. From the older experimental view-point certain interesting facts were determined. These were as follows: 1. The points of the esthesiometer always seem to be farther apart when one point is placed on one side of a [illegible] on the other. Thus, when one point is placed on the upper lip and one on the lower, they appear farther separated than if both points are placed in corresponding position on either lip. This in part accounts for the increase apparent when the esthesiometer is moved from the cheek to the median line in Weber's experiment. 2. Other things being equal, the points of the esthesiometer seem farther apart when they rest upon different tissues. Thus, for example, when one point is placed upon the mucous membrane of the lip and one point upon the skin, they seem farther apart than when both points are upon either the skin or the mucous membrane. 3. As a rule the points seem farther apart when they are on different sides of the median line than they do in corresponding positions when both are on the same side. This law does not, however, always hold good. 4. The direction in which the points are placed in relation to each other is of considerable importance in certain parts of the body, especially on the limbs. When placed transversely they appear to be at a greater distance from each other than when placed longitudinally. On the body proper there seems to be but little difference, while it is more marked on the face, and more so still on the limbs, especially the lower arms and legs. The cause of this is as yet unknown, but it may be that the skin over different muscles responds more readily to two stimulations than the skin over the same muscle when touched at two equally distant points. According to Vierordt the relative delicacy of the sense of locality at any point on the skin of a special portion of the body, as compared with that of the other points of the same portion, is a function of its mobility and increases proportionately to its distance from the axis on which that part moves, since it depends on the relative greatness of the excursions which it effects about its axis through the movements of the part concerned.

In applying the esthesiometer certain precautions should always be observed. The points should have the same temperature as the body. In one series of tests the operator should take especial care that both points are applied as nearly as possible *simultaneously*, as the element of time enters distinctly into our tactile impressions and the greater the time which elapses between any two impressions of a similar kind, the more readily are such impressions recognized as distinct. For this reason, also the points, when once applied, should not be moved, for if they be moved, a new sensation, or a series of sensations, will be produced, which will enable us to interpret the impressions more easily. It is a curious fact that, if two points be placed so near together that they are felt as only one, and a third point be drawn across the skin between the two, the sensation of a moving object can be felt, although its position cannot be localized. The impression produced by the points, moreover, becomes clearer the longer they remain in contact with the skin. Hence, in making comparative observations, the points should be held on each place for the same length of time. In addition to the simultaneousness of the touch the pressure at the two points should be as nearly equal as possible and as slight as possible. As we shall hereafter see, the ratio of the sense of pressure in different parts of the body varies considerably from that of touch, and the two different sensations should be carefully distinguished. For practical purposes, however, the amount of pressure exercised in ordinary cases when due care is taken is not sufficient to affect in any way the result. It is otherwise, however, when a different amount of pressure is exerted on the two points. The force of the stimulus produced at one point is liable so to act that the stimulus produced at the other is perceived but indistinctly or not at all. A third and obvious precaution to be observed in using the

esthesiometer, when testing corresponding portions of the body, is that the points should in each case be placed in the same direction, that is, longitudinally, obliquely, or transversely, as may be, and that they should be on exactly corresponding parts and at an equal distance from the median line. This is of special importance in pathological cases, where the esthesiometer is used for the purpose of diagnosis.

In an examination for physiological purposes we must also take into consideration the mental condition of the subject. Whenever the attention is strongly fixed upon any point in the body, sensations produced there by external objects are more readily and more quickly perceived than when the mind is occupied by other thoughts. Hence, when the attention is fixed upon the action of the esthesiometer, the points will be perceived more readily and more distinctly than would otherwise be the case. The readiness with which the points are perceived and their position determined varies also greatly with practice. Cold diminishes the tactile sensibility, as does also extreme heat. Hyperemia, as well as anemia, probably likewise diminishes it. The clinical value of the compass-point tests of epicritic sensibility are fully discussed in the article on *Anesthesia and Analgesia*.

Baresthesiometer.—The term baresthesiometer, from βάρος, weight, and esthesiometer, has been applied to instruments which are used to determine the delicacy of the cutaneous sense of pressure.

The first attempts to measure the cutaneous sense of pressure were made by E. H. Weber, who for this purpose used weights laid directly upon the parts to be tested, the muscular sense being excluded by firmly supporting the part to be examined upon some solid body. Various weights, as nearly as possible of the same size and same temperature, were applied in succession to the part, and the smallest difference which could be thus detected was carefully determined for each part. Weber himself had made use for this purpose of coins (thalers) which he laid upon the forehead, the head being supported, and thus he obtained some important results. According to his researches, the sense of pressure varies much less in the different parts of the body than the sense of locality, and does not vary in the same proportion in the different parts. In the place of coins Kammler and Aubert made use of small discs of cork or elder-pith, on which weights could be placed, while Dohrn estimated the sense of pressure by means of a blunt point attached to the arm of a pair of scales. In 1863 Goltz published the account of his apparatus, by means of which he sought to determine the smallest *rhythmical* pressure which can be perceived on any given part. For this purpose he made use of an india-rubber tube, both ends of which were closed and which was rendered tense by being filled with water. The pulsations produced by the experimenter at one end of the tube were transmitted to the other end, which was laid upon the part to be tested. Goltz's results corresponded with those of Weber for the *sense of locality*, except that the tip of the tongue was found to be proportionately much less sensitive to pressure.

To determine the delicacy of the sense of *variation of pressure*, Eulenburg used the baresthesiometer which bears his name (Fig. 2155). It consists simply of a hard-rubber plate, on to which is screwed a spiral spring through whose greater or lesser tension a stronger or weaker pressure can be exerted on the plate. This spring is placed inside a case, and can be more or less compressed at will by means of a guiding rod. Through a toothed wheel, which is placed in connection with this rod, an index is set in motion, which marks on a dial plate the amount of tension of the spring, thus showing the strength of the pressure exerted. Each figure on the dial corresponds to a pressure of one gram. Eulenburg found that the sensibility to variations of pressure was most delicate on the face, especially the forehead, then on the lips, the back of the tongue, cheeks, and temples. Here it is $\frac{1}{30}$, often $\frac{1}{40}$. On the upper extremities it is $\frac{1}{20}$ to $\frac{1}{10}$, and does not vary much in the different parts. In the lower extremities the anterior portions of the lower leg and thigh seem to possess the greatest sensibility; next follow the back of the foot and dorsal surface of the toes, while on the plantar surface of the toes, the sole of the foot, and the posterior portions of the lower leg and thigh the sensibility is much weaker. Löwitt and Biedermann found that by the finger tips the differences between weights which bear to each other the proportion of 29 to 30, could be appreciated, provided the weights were not too light nor too heavy. The power of determining variations of pressure varies in accordance with the amount of the pressure. Except perhaps for minimal pressures, the greater the initial pressure the greater must be the increase of pressure in order that a variation may be

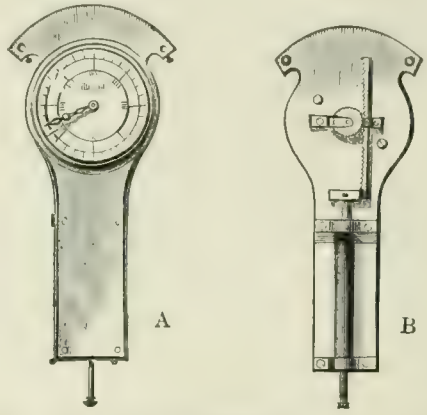


Fig. 2155.—Eulenburg's Baresthesiometer. *A*, Front view; *B*, back view.

felt. These instruments for determining the pressure threshold have been superseded largely by the use of von Frey's hairs, or the pressure esthesiometer of Head. The use of these instruments has afforded entirely new insight into clinical neurology. The chief features of deep sensibility in its relation to clinical neurology, as determined by the Head or Cattel instruments, are fully discussed in the article on *Anesthesia and Analgesia*.

Thermesthesiometer.—For measuring the sensibility of differences of temperature, Weber used two long glass phials filled with oil, into each of which he introduced a thermometer, passing it through the stopper. By means of this apparatus he found that the skin of the face was the most sensitive, especially that of the eyelids and cheeks. The lips, on the contrary, which are more sensitive to sensations of place, are less so to those of temperature. Moreover, the sense of temperature, as tested in this way, instead of being greatest in the middle of the lips, is greater on the lateral portions of the upper lip, greatest on the cheeks, and less as we approach the median line. In 1866, Eulenburg described his thermesthesiometer. The instrument consisted simply of a "frame" and two thermometers attached thereto. For "frame" he made use of Sieveking's esthesiometer, to the bar of which he fastened two exactly similar thermometers which corresponded accurately to each other. Their lower ends were drawn into broad glass bulbs, and flattened at the bottom so as to rest readily upon the skin. These thermometers worked like the points of the esthesiometer, one of them being fixed at the end of the bar, while the other could be moved along it as desired, and be fastened at any distance by means of a screw. Thus the distance between the thermometers was determinable at will, and could be

estimated by a scale marked on the bar. In using this apparatus, one thermometer was heated or cooled as desired, while the other was left at the temperature of the room. In the following year, 1867, Nothnagel published a series of very careful investigations into the cutaneous sensibility of the temperature, in making which he used a special instrument. Nothnagel's thermesthesiometer consists of two exactly similar cylindrical vessels, two and a half inches high and one and a half inches in diameter. Their walls are made of wood and are double, some poorly conducting substance, as ashes, being placed between the two parts. The bottom is formed of copper, a good heat conductor. On the top of the vessel is a tightly closing wooden cover which moves on a hinge and which has an opening on one side. Corresponding to this opening there rises perpendicularly from the edge of the vessel a piece of wood to which are fastened two rings. Through these rings and through the opening in the cover a thermometer is thrust into each vessel, which is partially filled with water, whose temperature may readily be rendered different in the two vessels by plunging into it some good conductor, which has been previously heated or cooled. The vessels should be placed rapidly one after the other on the part to be examined, and the time of contact should last until the subject has formed a judgment in regard to the temperature. Care must be taken that the whole surface of the bottom of both vessels should rest against the skin, since, as is well known, the strength of the impression and the delicacy of the sensibility to temperature grow with the increase in the number of nerve ends affected. By this means Nothnagel determined that the greatest capacity for distinguishing differences of temperature exists when the temperature is between 27° and 33° C. (80.6° and 91.4° F.); up to 39° C. (102.2° F.) it is but slightly diminished, but from thence to 49° C. (120.2° F.) it diminishes rapidly, and at the latter point pain occurs. From 27° to 14°C. (80.6° to 57.2° F.) the capacity diminishes in much the same ratio as from 33° to 39° C. (91.4° to 102.2° F.), but between 14° and 7° C. (57.2° and 44.6° F.) it falls off rapidly. He found that in different parts of the body the following differences in temperature could be distinguished:

	Centigrade.
Sternum	0.6°
Chest, upper and outer portion	0.4°
Epigastrium	0.5°
Abdomen, upper lateral portion	0.4°
Middle part of back	1.2°
Lateral portions of back	[illegible]
Palm of the hand	0.3–0.4°
Back of the hand	0.3°
Forearm—extensors	[illegible]
Forearm—flexors	[illegible]
Upper arm—extensors and flexors	[illegible]
Dorsal surface of foot	0.5°–0.4°
Lower leg—extensors	0.7°
Lower leg—flexors (calf)	[illegible]
Thigh extensors and flexors	0.5°
Cheeks	0.4°–0.2°
Temples	0.4°–0.3°

The sensibility to variations of temperature seems duller as we approach the median line. The hand and fingers are generally alike, the lower arm more sensitive than the hand, and the upper arm more so than the lower arm. By extreme degrees of heat or cold a thermanesthesia is produced. Anemia increases sensibility to temperature, hyperemia is said to diminish it.

Kronecker's thermesthesiometer resembles Eulenburg's, but the latter's thermometers are replaced by metal tubes, each divided nearly to the end by a partition, as in a double-irrigating catheter. Through these water of a fixed temperature can be caused to flow

Goldscheider studied the topography of the temperature sense by means of [illegible] with a round contact surface one centimeter in diameter. He also used in other experiments a metal globe which could be heated or cooled.

The recent work of Head points to the fact that two types of thermal recognition are present in the human body. One that distinguishes between slight variations in temperature-epicritic thermal sensibility, and that which distinguishes only between extremes of heat and cold protopathic sensibility. These are subserved by quite different receptors. These are tested often by ordinary test-tube methods. Numerous electrical thermesthesiometers have been devised, Mills of Philadelphia having constructed one of the latest. The clinical value of the information given with reference to epicritic and protopathic heat sensibility is very great. One may be lost without the other. In general, as in a neuritic process, both may be gone, but in certain cord lesions (hematomyelia), there may be a loss of protopathic and no loss of epicritic sensibility. Such a patient cannot distinguish between boiling and freezing, but may accurately say warm or cool. The significance of these tests in clinical neurology has been discussed in the article on *Anesthesia and Analgesia* in Vol. I.

SMITH ELY JELLIFFE

Estienne, Charles.—A distinguished French anatomist and practitioner of medicine of the first half of the sixteenth century. He was born at Paris about the year 1504. His father and his elder brother Robert were among the most celebrated printers of that period, and—like all those who presided at the birth of this art—they were men of great cultivation. Charles, the younger brother, after receiving a brilliant general education, devoted himself to the study of medicine and was given the degree of Doctor of Medicine on June 20, 1542. France was very much disturbed about this time by the opposition offered to all attempts to reform the prevailing religion, and Robert Estienne, who had actively espoused the cause of Luther, was soon made to feel that it was no longer safe for him to remain in Paris. He accordingly fled to Geneva, in 1551, leaving the management of the printing establishment in the hands of his younger brother, who by this time had become a physician of considerable distinction. In religious matters Charles was not in sympathy with his brother Robert. He remained a staunch Catholic, and the king (Francis II.), shortly after Robert's flight to Geneva, appointed Charles Printer to the Court. Despite the royal favor and the great fame which the Estienne establishment had acquired, he was unable to make a financial success of the printing business. The debts steadily increased, and finally his creditors threw him into a debtors' prison, where he died in 1564, at the age of sixty.

Charles Estienne owed his fame almost as much to his knowledge of botany as to the fact that he was an original investigator in the domain of human anatomy. His treatises on the former subject were six in number, and they were published separately at different times between the years 1535 and 1543. The book which he wrote on anatomy was published first in Latin (1545) and then in French, and the title which it bore in the latter language reads as follows: "La dissection des parties du corps humain, divisée en trois livres (avec les figures et déclarations des incisions par Estienne de la Rivière, chirurgien), Paris 1546.

A. H. B.

Estill Springs.—Estill County, Kentucky. These springs are located at Irvine, forty-six miles east of Lexington, 130 miles east of Louisville, and 130 miles south of Cincinnati, on the Louisville and

Atlantic division of the Louisville and Nashville Railroad. The modern hotel is beautifully situated on the eastern side of a high mountain, in the midst of a thirty-acre lawn studded with original forest trees. The farm connected with the springs comprises 830 acres. We are indebted to the United States Geological Reports for the following analysis, made by Dr. Robert Peter:

One United States Gallon Contains:*

Solids.	Red Sulphur Springs (near saloon) Grains.	Chalybeate Spring.† Grains.
Sodium carbonate	1.16	...
Calcium carbonate	11.66	9.32
Magnesium carbonate	4.64	2.93
Iron carbonate	...	1.75
Sodium sulphate	9.91	.58
Potassium sulphate	5 24	.58
Calcium sulphate		16.32
Magnesium sulphate	.58	9.91
Sodium chloride	5.24	.58
Alumina		Trace.
Silica	.58	1.75
Organic matter	2.33	8.16
Total	41.34	51.88
Gases.	**Cubic inches.**	**Cubic inches.**
Hydrogen sulphide	0.26	...
Carbonic acid	18.98	15.68

The following analysis of the white sulphur water was made by Professor J. H. Kastle, professor of chemistry, State College of Kentucky.

One United States Gallon Contains:

Solids.	Grains.
Calcium carbonate	15.3
Calcium sulphate	8.5
Magnesium sulphate	10.1
Sodium chloride	5.3
Potassium chloride	1.5
Lithium chloride	1.0
Silica and insoluble residue	2.1
Total	43.8
Total solids by evaporation	46.6
Hydrogen sulphide	1.4 Cubic inches.

The waters are principally of the light sulphureted type, with one mild ferruginous spring. Another spring in the neighborhood, termed by Walton the "Irvine" spring, is purgative, containing about 256 grains of sulphate of magnesium to the gallon. Besides the hotel there are cottages. The table is supplied from the large gardens of the springs. Fine bowling alleys, tennis courts, billiards, and many other sports are at hand for the entertainment of the guests. The springs grounds adjoin Irvine, a town of about 1500 inhabitants.

Emma E. Walker.

Estlander, Jakob August.—Born in Helsingfors Finland, December 24, 1831, he was graduated from the university in that place in 1858. After studying for two years in Paris and London, he was appointed professor of surgery at the University of Helsingfors, a post which he filled for his entire professional life. He died March 4, 1881, in Messina whither he had gone in the hope of regaining his health which had long been failing.

He was the author of numerous articles in surgical subjects published in the medical journals of France and Germany as well as of his native land. The operation which bears his name was described in an article entitled "Résection des côtes dans l'empyème chronique," published in the *Revue de médecine et de chirurgie*, 1879. Other papers written by him were: "Ueber Chorioiditis nach febris typhosa recurrens," Ueber Brand in den unteren Extremitaten bei exanthematischem Typhus," and "Methode d'autoplastic de la joue ou d'une lèvre par un lambeau emprunté à l'autre lèvre." T. L. S.

Ether.—In medicine and pharmacy the word *ether*, unqualified, means, as it does in common parlance, the body *ethyl oxide* $(C_2H_5)_2O$, formerly, but improperly, called *sulphuric ether*. Ether is a product of reaction between sulphuric acid and alcohol, and is obtained by distilling a mixture of these two bodies, and purifying the distillate. Under the simple title *Æther*, Ether, the United States Pharmacopœia recognizes an ether of standard purity, "composed of about ninety-six per cent., by weight, of absolute ether, . . . and about four per cent. of alcohol containing a little water."

Ether is "a transparent, colorless, mobile liquid, having a characteristic odor, and a burning and sweetish taste. Specific gravity: 0.716 to 0.717 at 25° C. (77° F.). Soluble in about ten times its volume of water at 25° C. (77° F.), with slight contraction of volume. Miscible, in all proportions, with alcohol, chloroform, petroleum, benzin, benzene, fixed and volatile oils. Ether boils at about 35.5° C. (96° F.), and it should, therefore, boil when a test-tube, containing some broken glass and half filled with it, is held for some time in the hand. Ether is highly volatile and inflammable. Its vapor, when mixed with air and ignited, explodes violently." (U. S. P.)

Ether tends to decompose by prolonged keeping, developing, as one product, acetic acid. For use as an anesthetic, ether ought to be pure and of standard strength. In all cases of suspicion, therefore, the surgeon should test his sample by the following simple procedures: 1. Let soak in the ether for ten minutes a piece of pale blue litmus paper, previously moistened with water; the paper should not redden, thus showing the ether to be free from acid. 2. Pour about two teaspoonfuls of the ether upon a piece of clean blotting-paper, free from smell, and let it evaporate; as the last of the ether is dissipated, no foreign odor should be perceptible on the paper, showing absence of impurities. 3. Saturate some water with the ether, and then shake together, in a graduated test-tube, 20 c.c. of such aqueous solution of ether with an equal bulk of the ether itself. Upon standing till the two fluids separate, the layer of ether should not measure less than 19.8 c.c., thus showing an absence of undue amount of alcohol or water—in other words, that the ether is up to standard in strength.

By reason of its extreme volatility ether is best kept in hermetically sealed tins. In bottles, whether cork- or glass-stoppered, leakage by evaporation is almost certain to occur, especially during transportation. Extreme inflammability is another property of ether requiring especial precautions in handling the fluid, and a point often overlooked is that air even moderately charged with ether vapor is explosive.

Ether is a conjoint local irritant and constitutional narcotic. Being of high diffusion power, it is readily absorbed by living tissues, and so speedily declares its influence. Applied in full strength to the skin, and prevented from evaporating, it quickly reddens, and in time will blister. Absorbed into the blood, ether disturbs nerve function by attacking first and more profoundly the nerve centers, and secondly, and with less intensity, the nerves themselves. Of the nerve centers, the cerebrum seems to be the most sensitive to the ether influence, the disturbance being first a

* Converted from parts per 1,000.

† Alkaline calcic chalybeate.

conjoint excitation of the emotional and blunting of the intellectual faculties, and finally an abrogation of all mental phenomena, and unconsciousness so absolute that upon awaking there is not even that vague apppreciation of the duration of the narcosis that follows ordinary sleep. Next to the cerebrum suffers the sensory tract of the spinal cord, the affection being a progressive blunting of perceptivity, and next again the motor tract, suffering first by paresis and irritation, and finally by full paralysis. Lastly, the medulla oblongata becomes involved, its sensory centers, as in the case of the cord, succumbing first and its motor centers last. Upon the nerves ether has a paralyzing power similar to what it exerts upon the centers, but the influence is so feeble as to be producible only by direct application of ether to an exposed nerve. In impregnation of the blood with ether, death of the subject by paralysis of the medulla will take place before there is any obvious impairment of conductivity on the part of the nerve trunks. Of the great functions, *heart action* is stimulated by ether, the pulse of a healthy subject rising in force and frequency, and maintaining such quickened and deepened action even through a long and full narcosis. In profound etherization, however, the heart is weakened, but the effect is always insignificant as compared with the weakening wrought by chloroform, and in death by ether the heart is still irritable. *Arterial tension* is increased at first; in part, doubtless, as a result of the increased heart action, but in part also, apparently, by vasomotor spasm. Later in the narcosis the blood pressure falls. *Respiration* is primarily stimulated, but secondarily depressed, until in full ether narcosis the breathing becomes slow and shallow; and, in case of overdosing, respiration is the function whose failure produces death. From the experiments of Knoll it would appear that these respiratory derangements are caused by direct action of the ether upon the respiratory centers. Functions presided over by the *sympathetic* nervous system are but little disturbed by ether. The *stomach* is easily upset by ether; full doses given by swallowing are repulsive and sickening; and after ether inhalation nausea and vomiting are common occurrences, especially if the narcosis has been of considerable duration, and especially, further, if an ether of inferior quality has been used.

Ether may be administered by inhalation or by the stomach. For inhalation, and the anesthetic use of ether, see *Anesthesia, General Surgical*. By the stomach, from one to two teaspoonfuls is the average dose, best given in from eight to ten measures of ice-cold water, sweetened, if so preferred. Ether so taken is, however, a repulsive medicine, being offensive to the taste and tending to choke, because of its pungency. But for internal administration the common practice is to prescribe the pharmacopœial preparation entitled *Spiritus Ætheris Compositus*, Compound Spirit of Ether, or Hoffman's anodyne. This preparation is compounded of 325 parts, by measure, of ether, 650 parts of alcohol, and 25 parts of ethereal oil. It is a colorless volatile fluid, smelling and tasting of its three powerful ingredients. It forms a milky emulsion on admixture with water. It is used as an antispasmodic and general nervine and cardiac stimulant, and is given in average dose of from half a teaspoonful to one or two such measures, in water, plain or sweetened. In the United States Pharmacopœia there is also official a preparation entitled *Spiritus Ætheris*, Spirit of Ether, a preparation consisting of 325 parts, by measure, of ether, and 675 parts of alcohol in mutual solution. This spirit may be given as an internal medicine in doses of one or two teaspoonfuls, administered in a goodly quantity of iced water, plain or sweetened.

A peculiar application of ether is the driving of the fluid, in atomized spray, upon the skin for the purpose of freezing that texture by the cold developed by the evaporation of the ether—such freezing being for the sake of the anesthesia that attends it. The procedure is appropriate only for brief and superficial surgical operations, and often is more painful than the [illegible]

See *Anesthesia, Local*.

Edward [illegible]
R. J. L. Scott

Ethics, Medical.—Ethics, the dictionary says, is "the science of human duty; the body of rules of duty drawn from this science; a particular system of principles and rules concerning duty, whether true or false; rules of practice in respect to a single class of human actions—as political or social ethics; medical ethics." I have ever been of the opinion that a gentleman required no rules of duty. But duties are many, and the rules of duty may, and should, be learned. The ten commandments may not be required by the virtuous, but when learned by the young they have contributed to keep him—aye, to make him—virtuous. That is why the medical student should learn the ethics of his profession before the temptations and asperities of practice, and bad examples, have numbed his finest feelings. That is why, in my opinion, the teaching of medical ethics should be a part of our undergraduate courses, and a medical school without them does not fit the coming generation of physicians—while conscience is being clouded by modern commercialism—for their sacred vocation. That is why the American Medical Association, after abolishing its punitive code of ethics ten years ago, has compiled and promulgated as an advisory and suggestive document, the "Principles of Medical Ethics." Its chapters are three: first, the duty of physicians to their patients; second, the duty of physicians to each other and to the profession at large; and, third, the duties of the profession to the public, as teachers of public hygiene, of sanitary matters in daily life and in epidemics, and on charlatanism, which is rampant in every country and constitutes a permanent danger even more threatening than epidemics.

A year ago, Dr. L. Fischer of Vienna published a book (Ärztliche Standespflichten und Standesfragen, Vienna, 1912) on the duties of the medical profession and general professional questions. In his historical review, he speaks of jealousy and enmity as the peculiarities of medical men: "Invidia medicorum pessima," and "Cave collegam" were proverbial. The book is still waiting for a translation. One of its best chapters is that on the mutual relations of medical men. Galen himself complained of having suffered much, even physically, from the jealousy of the doctors. The relations between the members of the medical profession remained bad through centuries, though professional leaders and governments tried to make the doctors behave like gentlemen. In the tenth century, Izaak Judæus, in the fourteenth, Henry de Mondeville, preached concord and harmony; they even practised what they preached. In vain! Through centuries, statutes of associations, faculties—for instance, those of the chirurgeons of Paris, 1370—the barbers of Alsace, the medical faculties of Leipsic (1309), Cologne (1392), Vienna (1494), contain all sorts of rebukes, reprimands, fines, and even incarcerations on account of unethical behavior. Johannes Peter Frank was so disgusted with the behavior of doctors when they met in consultations as to advise the calling in of the police on all such occasions. That was about the end of the eighteenth century. It was the very time (1799) at which the Maryland Medical and Surgical Faculty, according to Eugene Fauntleroy Cordell (The Medical Annals of Maryland, 1903, p. 31) framed regulations which gave its president authority to fine any member, acting at a meeting in a disorderly manner, a sum not exceeding ten dollars, or, if the offense were considered sufficiently serious, to eject him, with the

consent of two-thirds of the members present and after all, they did not know of fee splitting and contract practice in those times.

These conditions were the same in all countries—Germany, France, Switzerland, Italy, and Great Britain. It was in the last-named country that Percival wrote in 1803 his book on ethics which was the foundation and guide of the American Medical Association (1847) until the punitive "Code of Ethics" was replaced by the "Principles of Ethics" at the general meeting in New Orleans, in 1903.

The history of what may be styled the business relations of practitioners is quite extensive. No "barber," chirurgeon, or practitioner was entitled to take a case which was under the treatment of another, unless the predecessor was notified, paid, and decently discharged. The large number of regulations, orders, and sometimes heavy fines emanating from governments and faculties prove the frequency of transgressions. The good "olden times," the "golden age," of the past was not what we—with all our justifiable complaints of to-day—would wish to see return. Consultations were always frequent—either desired or feared. Hippocrates says that quacks refuse to call other practitioners but that a physician will, in a case beset with difficulties and dangers, demand the presence of a colleague without any injury to his own reputation. Still, the anxiety of the patient and his friends overdid the practice of calling consultations. Pliny reports that the monument of the Emperor Hadrian was inscribed "turba medicorum perdidit Caesaren" (the large number of doctors killed the Emperor). Henry IV. of France, calling (1594) upon one of his state officers who suffered from retention of urine, found him surrounded by sixteen doctors. The patient is still dead. Some of the regulations regarding consultations were quite strict. Now and then it was ruled that the youngest doctor talked first, in other cases it was the oldest and most mature.

The relations of the practitioner and the apothecary were considered suspicious at an early time. The statute of Benevent (1207), the medical rules of the Emperor Frederick II (1241), the regulations of the city of Marseilles (1255) and those of Constance (1387), are very emphatic in their expressions concerning their pecuniary relations. Annual presents were limited to a certain amount, or were prohibited. In several cities, during the fifteenth and subsequent centuries, the doctor was warned not to send his patients to a particular apothecary. The question whether the apothecary was obliged to furnish medicines gratis to practitioners or to their families was discussed by the Faculty of Vienna in 1628. Its decision was quite positive. No such obligation existed, but the apothecary was permitted to be guided by reasons of friendship.

Human nature, good and bad, seems to be the same in all centuries and all peoples. The outcome of what existed centuries ago is at the present time the taking of "commissions." There are those in the practice of medicine who demand and take commissions. What is a commission? An agent receives it when or because he supplies to a tradesman a new customer. It is not difficult to determine who pays for it. Is it the employer? or the customer?

It is an indirect tax to be paid by the latter, viz., the customer, who is robbed in order to sustain a high tariff. Commissions are asked from and paid by apothecaries, truss and bandage makers, instrument manufacturers, even from and by poor nurses. That is a shameful but frequent occurrence. I know that a competent person who asked for a weekly payment of fifteen dollars was in the habit of offering a "commission" as a remuneration to the practitioner who was requested to employ her. This occurred a year ago, not centuries ago; in New York, not in Sing Sing. Unfortunately, this is not an unusual case. It merely proves that the practice of medicine is, to many, a shameless trade instead of a sacred vocation. The same unprincipled method is followed in the relations of the practitioner to the consultant, who is called in only because he consents to divide ("split") his fee with the man who calls him in. This iniquity is no exception; on the contrary, it is quite frequent. In New York and other large cities it is only a small number of surgeons who are known for their objections to this nefarious practice and their persistent refusal to submit to it. The very fact that medical associations and public hospitals have felt obliged to stamp the practice as nefarious, even to threaten transgressors with expulsion, proves its frequency. Its extermination is not easy. If the consultant no longer pays cash, he has been known to help his needy or greedy employer with a "loan." There is no law or rule that may not be either broken or circumvented by those in the low ranks or by those of high standing. Unhappily, doubtful or vicious habits are more readily established than virtuous precepts. That is why it is so much easier to influence favorably those who are still young and not demoralized by poverty or the temptations of years of detrimental opportunities, and why the neglect of teaching ethics during undergraduate instruction in our medical schools is a reprehensible omission. Indeed, advanced classes of medical students have felt the want of it and have invited it.

Hippocrates has the following sentence: "I shall give nobody a death-working remedy, though I may be requested to do so, nor shall I suggest anything of that nature."

What has been called euthanasia is not meant to favor the suffering or dying, but to relieve and please the living egotist. Bacon wanted the dying or moribund removed because to him the sight of pain was distressing. A hysterical—and for that reason, fashionable—poet sees in the dying "agony" only. That is Maeterlinck. When a patient is "doomed"—he makes that prognosis out of ignorance or craziness (Galton has a special class for poets and insane)—he blames the doctor for not relieving Maeterlinck of Maeterlinck's horror. I was present when a doctor of divinity told a houseful of doctors of medicine that they must give a deadly dose to a patient who is sure to die. "Sure to die," prognoses are rarely made by the knowing. They require the insolence of ignorance. Of the latter, no one is deprived by a one-sided instruction (called "education"). That is why every "medical sect" for a hundred years past has gathered its converts and adherents in "professional" circles, particularly among those of all possible sexes whose studies and convictions are based on faith exclusively. To this class belong clergymen and lawyers.

I know of no better teacher of the "principles of ethics" than the rules laid down by the A. M. A. Its collection of leaflets should be in the hands of every one, to be read occasionally as a welcome reminder. A good doctor should have it on his shelf next to his Bible. As its contents teach the doctor's duties to himself, to his profession, to his medical neighbor, and to the community, my remarks may be quite brief.

The young and the old doctor's duty to himself is his membership in the medical society of his county, State, and the A. M. A. I have met hundreds of men who belonged to none of them, but none of them filled me with confidence in their judgment or general sense of responsibility. The County Society, like every scientific gathering, is the very place to teach and to learn, the latter more through discussion than the reading of papers. Briefly, membership in the County Society is as significant as naturalization of a foreigner—at the proper time. Omission of that duty or opportunity means bad citizenship.

Be careful when you make a prognosis. In the presence of a patient afflicted with a fatal disease, be

rather optimistic. That is no reason why a reliable or cautious member of his family should not learn the truth. I have made many mistakes in that way. Good-naturedness and the fear lest a fatal prognosis would disturb the family nursing and reach the patient after all have prevailed upon me frequently—mainly in my younger years—to give an unjustifiably good prognosis, which finally was refuted by the outcome. Our feelings and temperaments must be watched. After all, however, our optimism is a boon to the patient. Hope and assurance are better nerve stimulants than valerian or nux vomica. To tell a patient he has to die is a culpable brutality. Beware, however! Patients who tell you they want to know the worst, deceive you and themselves. The teaching of Richard Cabot in connection with that problem is a mistake which injures the patient; and Grover Cleveland's address delivered before the Medical Society of the State of New York some years ago was the result of insufficient information on the part of that great, true, and otherwise wise man. Concealing a dangerous truth is no "lying."

Patients should be filled with hope in the way in which their ailment is described to them. They take the word "cancer" as a death warrant, and the shock and fear kill them before their time. Let them understand that they have a tumor which should be removed immediately, or, when inoperable, should be treated medicinally only.

Your straightforward inhumanity should not add to the gravity of the calamity. The word "consumption" takes the same rank in their imagination. It is a sentence of death. It should never be used. Health Department officers who in their thousands of cases use the word officially prove that they obtain more callousness in their bureaucratic desk work than feeling for their unfortunate neighbors. Tell your patient he has "tuberculosis," and that in order to escape "consumption" he must obey certain rules of diet, and hygiene, and proper medication to get either well or surely no worse. To tell a young woman with heart disease that no medicine in New York or Brooklyn will cure her, is brutal and ignorant. Such wild talk and careless phraseology harms the sick and drives them into the arms of the quacks of either sex. All these warnings have been given thousands of times these 7,000 years, but we doctors are apt to forget both facts and ethics.

In our vocation we have to deal with no crystal, or a machine, but with the life of a fellow-being. We are, at the bedside, no longer naturalists, no longer mere medical men, but physicians. If we cannot cure or restore, we can improve. If neither, we can cheer, and that is improving.

One of our obligations to the community is frequently forgotten in the following way: The rules for admission to both public and private schools require that a child taken with a contagious disease must be isolated, and no child of the same family must return to the school within a legally determined period. Untold dangers and many deaths may occur in consequence of not reporting a communicable disease. A scarlet fever must not be declared a stomach rash; measles, a cold; chickenpox, an intestinal autoinfection; and diphtheria, a mild sore throat. Such a criminal transaction has been the cause of many like cases in the same family and its neighborhood, of an epidemic, of the closure of many schools, of untold undertaker bills. .

Ethics are disregarded in a great many other ways. We are prone to complain of the rapid invasion of proprietary foods and medicines, but the vast majority of the very prescriptions of the doctors, which are recorded in all the apothecary shops, contain proprietary medicines, nostrums, quackishnesses "made in" America, Germany, France. Nor is it less unethical to shift the responsibilities of a doctor's office on less competent shoulders. The great majority of the so-called laboratories [illegible] by incompetent people. [illegible] our general practitioners refer the simplest examinations of urine or sputum to them. [illegible] expense, they decrease the respect due to the practitioner. The practitioner also acts in this way unethical in a great many ways [illegible] perform for his patient a simple work; moreover, it detracts from the dignity and humbles the position of the practitioner in the eyes of the public, which is taught by its very practitioners that they are unable without outside help to take care of the sick.

There are a few rules to be remembered by the young doctor. When your medical neighbor has patients while you are still waiting, never grudge him his own, and wait—as he has done. When the first patient has turned up, never feel that you own him. When your neighbor is well spoken of, do not believe that your reputation suffers because he is eulogized. On the contrary, you miss for many reasons, a great deal when you omit praising a colleague who deserves it. It is better that patients should seek you than that you should run after them. When your patient leaves you for some other doctor, it depends on your temperament, or vanity, or needs, whether you feel chagrined—but do not blame the doctor who is called in your place. On the other hand, when another doctor robs you of your patient by hook or by crook—they say that such things do happen—be sorry for that doctor and for the profession he should not belong to, and be glad that you are not the other man, but a gentleman. Remember that a gentleman should find it easy to compete honorably; when you are treated in that shabby way it worries you, but *you* are the gentleman, and people will eventually find you out. Not to take honest competition on the part of others kindly, shows disregard for the rights of others, either doctors or patients, and bad citizenship, and exhibits jealousy, avidity, and senility of the young or the old heart.

The commercialism which is the signature of our era has invaded industries, arts, sciences, and the professions, but it has not proved so detrimental here as it has in Europe where poverty is still greater, and the innate pride of our democratic citizens is absent. Still, we have not escaped the hypocrisy of the worst forms of fee splitting or contract practice. No rule, no code, will ever make a gentleman out of an evilly disposed or low-bred person. No law can. But their teaching may guide and warn the inexperienced, even in a time which makes honorable competition unusually difficult.

Still, conditions were worse for us some time ago. When the facility of obtaining a diploma and of the license to practise filled the profession with undesirable men and women, the ideal of what a physician should be was crowded to the wall. It is only with the growing difficulty of matriculation and the increasing severity of examinations—particularly also the establishment of State license boards—that the number of underweight doctors has become smaller, and the average standard of the well-informed, well-brought-up, and well-behaving, and erudite doctors immensely higher. That is why the humanitarian endeavors of the altruistic part of the community find their support more than ever among such members of our profession as look upon their duties beyond the field of mere prescription writing and bone-setting.

Section 7 of Chapter II of the "Principles of Ethics" of the A. M. A. declares public advertising to be incompatible with honorable standing in the profession. A better phraseology [illegible] sentences cannot be imagined. Without one telling them the public will find out what every one of us is made of. Whoever is a thorough specialist will soon be appreciated and favored by his professional colleagues. No advertiser has ever lived to see policemen required to protect his hall door against the

storming of his office by uncontrollable throngs of would-be patients. It was a foreign tourist, who, after a few weeks on the railroads in this country, tried to refute an American practitioner who, after a practice of sixty years, defended the American doctor against the charge of universal advertising, and proclaimed in one of the greatest medical weeklies in Germany, that *he* had been in America and knew better, for he and his fellow-travellers had seen ever so many shingles with the word "osteopath" inscribed on them. Sapienti sat.—

A. Jacobi.

Ethidene Bichloride.—*Ethylidene Chloride:* $CH_3.CHCl_2$. This is an ethereal body, isomeric with and much resembling ethylene bichloride. It has been experimented with as an anesthetic, and has been found to operate after the general manner of chloroform, including the occasional killing of a subject. It is said to be less depressant to the heart, and therefore safer than chloroform; it is administered similarly to chloroform.

Edward Curtis.
R. J. E. Scott.

Ethnology, Medical.—Within the last few years many physicians have observed facts which indicate that the law of adaptation to environment applies strictly to man, and that if a type which has been evolved as fittest for survival in one place, migrates to a new environment to which it is not adjusted, it suffers from special diseases due to the new adverse factors against which it has no defenses. We have known for a long time that races disappear if they migrate to a climate markedly different from their ancestral one, but the newly discovered facts show that we are tied by a much shorter tether than the older ethnologists realized, and that even a minor change of climate will adversely affect those variations, which are the least adjusted to the new conditions, while the individuals which happen to vary in the opposite direction of a more nearly perfect adjustment will be in better health and eventually survive as the fittest. Indeed, the evolution of the present races and subraces from common ancestors could not have been accomplished by any other process than by the survival of the fittest, variations among migrants, and the destruction of the unfit. There is still some question as to whether mankind has descended from one or two or several pre-human or anthropoid types, but there is no question that there has been a common ancestor of all existing types if we go back far enough. That is, there was a cradle of the human race—a place of origin—and from this place individuals or groups spread outward in search of new feeding grounds. These early movements were necessarily very slow, and probably no tribe was ever able to go so far as to meet an environment which killed all its members. Some survived and these fittest ones may have been very few indeed to have perpetuated the new type. Thus new races arose as the migration carried man over the whole earth.

There is not space here to give the proofs of this universal law of a tendency to spread from a constant overpopulation, but the facts are recorded in the book "Expansion of Races" by the author of this article. What we must realize is, that there are perpetual streams of people toward places where there is more wealth per capita than at their respective birthplaces.

These movements are constantly taking some to places where lack of adjustment is causing them to sicken, and the science of medical ethnology takes congizance of the types which thus tend to die out, and also studies the diseases which cause the loss of vitality. This branch of demography has recently assumed more importance from the discovery that evolution by this process of killing the least fit may be very rapid. For instance, there is historic proof that the majority of the French women sent over to Canada by Louis XIV were blonds, probably from the northern third of France. The present population is very largely brunette. In Louisiana few if any blonds have survived, the pure French creole being almost invariably brunette. Such evidence is inclining us to the belief that the evolution of the subraces in Europe may have been very rapid and not the long process we once considered it. To be sure, a type once adjusted to a place will not change if it remains there and the environment does not change. The peasantry of Egypt, for instance, is essentially if not identically the same as it was many thousands of years ago, as shown by the pictures carved and painted on the walls of ancient tombs.

Before we can fully understand why certain diseases attack a type out of its proper environment, we must know the reason for the local evolution of all the various characters of every type of man—such as tallness, curliness of hair, and width of nose. We must assume that everyone of such characters has been of use, otherwise it would not have been created by that awfully expensive process of "natural selection." No one has ever detected nature doing anything so foolish as selecting the useless or harmful for survival. The struggle for existence is so severe that it requires only a slight advantage to survive a strain which might be like the last straw to men not so fortunate. Hence all such characters as distinguish one type from another must have been of vital importance, sometime, somewhere.

Physiology has scarcely a word as to the functions of the characters or differences between races of men. Take the beard, for instance. It is not a protection against cold, which requires fur or wool. In addition races living in the coldest countries may have no beard at all, and it may be abundant in hot places. Only recently has it been discovered that the beard is a vital protection against injury by the underbrush of forest-living primitive man in his hunting stage. Soldiers campaigning in countries where the brush is thick are often compelled to let their beards grow to prevent lacerations of the face and neck. It can well be seen that this protection would determine survival in competition with those not so guarded, and it is also evident that the women who never did any of the hunting or fighting in the forest had no need for the beard, and there was no selection in their case and no evolution as with the men. In the same way female lions and buffalos did not evolve the mane as a protection in fighting. Prof. L. W. Lyde, professor of geography, University College of London, has recently observed that the long-headed races, which are largely bearded, inhabit wooded districts and shun the open country, while the beardless or broad-headed Asiatic types live in the open or grass country and dread the forests.

In modern life there is then no known use for the beard, which persists in appearing by the law of organic inertia. There are no known ethnic diseases relating to the beard or its absence, and the hygienic discussions on this line are pure speculations. If the growth of the beard were an appreciable burden from the use of material needed for growth of other tissue, involution would quite promptly take place by the advantage in survival of those not so burdened.

If a change of environment makes a character harmful, its disappearance requires infinitely less time than its evolution. Beardless races which migrate to forest countries could not expect to develop this protection for many thousands of years, and that is one of the numerous facts going to prove that the American Indians are rather recent arrivals—speaking geologically. They have had ample time to modify other characters but have not developed new ones. They still closely resemble the Mongol tribes of

northeastern Asia, who have been proved by Dr. Alex. Hrdlicka to be the ancestors of the American Indian.

The beard, by the way, is a mere remnant of the hair which covered the whole body and which disappeared except in useful patches, because it became harmful. There is now no question that it persisted until long after man had developed a high degree of intelligence but had still retained some simian physical characteristics. Indeed there are actual prehistoric pictures engraved on stone or ivory showing this body hair. The harm of much body hair resulted from the inability to stand rapid daily changes of temperature such as must have characterized glacial times. The intelligence which permitted man to prepare and use hides of animals for protection not only prevented his own total extinction but gave such an advantage to those with the least hair, who could thus stand all extremes, that the involution must have gone on very rapidly. It is remarkable that the beardless races have little body hair and that the cross-section of the hair is nearly circular and the hairs straight; but that the bearded types have hair on the body also, and the cross-sections are oval or flat and the hairs more or less wavy or kinky. There is no known explanation of these facts, and of course, no diseased conditions are known to occur in those who markedly depart from the rule of their locality and ancestral type. The Biblical story of Jacob and Esau seems to be based on the struggle of these two types of forest and plains people for the possession of Palestine. The story is interesting as showing that hairiness is possibly a great disadvantage in places where nature has evolved a hairless type, but the matter has never been studied pathologically.

If an animal spreads north and south, the size of the varieties or species increases from the tropics to the arctics. This rule applies to man, but we have no explanation for this general rule. The shortest or pygmies are in the tropics and the tallest near the arctic circle—the Scotch and Pategonians. There are many exceptions to the rule, for instance, there are very tall natives of India and yet tall Britishers suffer from disease there much more than short ones. As a rule big Europeans do not last in tropical colonies, and the survivors of long tropical service are all short men like Lord Roberts and Dr. Livingston. No one has ever described any special diseases, which carry off or disable the biggest white men who take up tropical residence, and it must be a general reduction of vitality. I know of several who developed tuberculosis though apparently in the pink of condition, but the little men also become tuberculous and perhaps in greater percentage, so we are wholly unable to explain why tallness has developed, except the general rule, that among hand-to-hand fighters tallness must have helped in the battles to a large extent, and that the race became tall from survival of the fittest warriors, but that stature diminished where migration carried the type to where tallness was harmful in some unknown way.

In the matter of weight or bulk we are on safer ground, for there is little doubt that the universal slenderness of tropical races is of vast assistance in radiation and prevents the overheating so prone to occur in bulky men from cold countries. The exceptions to this rule in the tropics are sedentary aristocrats who are overfed and who are carefully protected against the climatic factors to which they cannot possibly be exposed like the slender low-caste coolies. In addition it seems that fat tropical natives are of short life. In cold countries it seems that stockiness or even bulkiness and fatness, irrespective of stature, are of great advantage in keeping warm, as the radiating surface diminishes in proportion to mass when the size increases. A mass of hot metal may take days or weeks to cool off, but if run into thin wire or broken into pieces the size of bird shot, it will cool in a few minutes. Stocky men are comfortable in cold weather with far less clothing than [illegible]. Heavy northern types are at a great disadvantage in all parts of the United States where [illegible] season or even where there is no cold [illegible]. Dr. Brandreth Symonds (*Med. Record*, Sept. 5, 1903) has proved from life insurance statistics that no men, more than twenty per cent. heavier than the average for their height and age, reach eighty years of age, and that practically all who do live longer than four score have been underweights who are more than twenty per cent. lighter than the average for their height and age. The overweights seem to die unduly from nervous, digestive, circulatory, and urinary diseases, probably due to eating too much for their requirements. That is, with lessened radiation they might need actually less food than the thin men, but consume more, which instead of being oxydized, is merely stored to clog the mechanism and perhaps poison the whole system. All this fully explains the Americans' general tendency to leanness as compared with their ancestors, and the pictures of John Bull and Uncle Sam are not fancies by a long shot. As far as known, the bulky men in northern Europe seem to have an advantage as to health and long life, but there are no statistics at hand to verify this conclusion.

Obesity and brawn are then exceedingly important matters in hot countries, not only as to hygiene and therapy, but also as to the selection of proper climates to retain or restore health when a change is needed and is possible. In the climatic treatment of tuberculosis, for instance, there is little doubt that weight has much to do with success in very cold climates and that the failures are largely in thin persons who cannot keep warm or comfortable even when oppressively overloaded with clothing. Conversely, heavy, bulky, or fat patients will rapidly get worse in hot climates or in the hot season, or even in mild climates where thin men recover. The heavy healthy man needs an amount of out-door exercise which would be fatal to a small thin man, and would quickly sicken or die if exposed to indoor sedentary conditions which seem to be ideal for certain small thin men. In no other maladjustment are the results of improper living so disastrous, as in the case of heavy men out of their proper environment.

The size of the nose and nostrils must be a very important factor in health because they vary so enormously from country to country. In hot places where we must breath more bulk of the rarefied air for the needed oxygen, the nostrils and nasal cavities are open and large to give free passage to the current, but the nose itself is very small. In cold countries, on the other hand, the air is condensed, less bulk needed and it must be admitted in a thin, ribbon-shaped stream so that it can be more easily warmed. Consequently the nose is large but the nostrils thin, and there seems also to be more warming surface on the turbinates than in tropical peoples. The nasal index (width divided by breadth) increases from the arctics to the tropics.

Races which inhabit elevated regions seem also to have special arrangements for their combination of cold and rarefied air, but the details have not been worked out. As between hot and cold countries there is an appreciable difference in the size of the anterior nasal bony aperture, and the matter must have vital bearings to cause such profound changes in the shape of the skull.

The large open nostril has long deen blamed for the respiratory diseases of tropical people who migrate to cold climates. Conversely the thin nostril and constricted nasal spaces of a northern race cause some kind of distress when it goes to hot places or elevated regions. How much disease results has never been reported but there is little doubt that the congestions and catarrhs so prevalent in America are [illegible]

due to our hot summers as to our cold winters. Pneumonia is almost an ethnic disease, since it is so prevalent among races which migrate. It killed the majority of the Eskimo who took up residence in New York or similar climates, and at one time it well nigh decimated Jamaica negroes at work on the Panama canal. In our elevated northwest country, pneumonia does not bother people much in winter, but prevails in the late spring and summer.

The recently discovered pictures of primitive Europeans, show that man then had a large prominent nose. During this long cold period there was a slow emigration to lands where the struggle for food was easier, the evolution of more brain ceased at once but the body gradually changed to fit it to the new climatic factors. The present lower races of limited intelligence are the descendants of these early escapes from the cradle of the race during the process of evolution of higher man. The stay-at-homes, who remained north under this cruel selection of the most intelligent, of course evolved the best and biggest brains and their descendants are the two main types now found in the northwest corner of Europe—the long-headed brunette primitive stock and its blond subrace, the Baltic, Nordic, or Aryan, which by the way, seems to be a very recent evolution.

Now these early escapes into hot climates would promptly redevelop the simian wide nose and open nostril, though they had previously evolved a big nose to fit them to the glacial cold weather. To accomplish this change there must have been the same diseases of maladjustment that we now see in the thin-nostrilled northern peoples who have wandered into hot climates. The American negro, who has made the reverse move, seems to be keeping himself alive for a while by escaping the cold and seeking indoor employment.

The open nostril of white infants and children would seem to be a disadvantage if they are exposed to cold, as their fathers are, but they survive with their mothers because they are more carefully housed. Indeed the short, stubby, turned-up nose of the baby is a real advantage in nursing, permitting it to breathe freely. Medical ethnology, then, would utter a warning against the excessive exposure of babies to very cold air. It seems almost a crime to say anything against the splendid modern fashion of keeping babies outdoors even in winter, but our besetting sin is carrying good things to such an excess that they become bad things. We must remember that the white baby was a tropical animal for nine months before it was born and thrives in hot climates during infancy, if properly breast-fed. There is some evidence of harm from undue exposure to cold air and mothers should be warned to arrange the covers so as to protect their babies from cold winds. The evident distress of a baby in a wind of any temperature makes us guard it instinctively, but in the matter of sleeping in its carriage on the porch we are liable to be a bit neglectful.

Italians less than five years of age have a death rate in Boston of 32 for males and 19 for females, as compared with the rate of 7.2 for all nationalities, while the babies from northwestern Europe have generally low rates.

It is interesting to note that the tropical or Arab horse has large open nostrils like a negro, its trachea and larynx are so large as to widen the space between the angles of the lower jaws, and its head is in line with the neck, so that when running there is almost a straight line from the nostrils to the bronchi permitting a free flow of air. It is also said to have larger lungs than the northern species. These characters are said to induce bronchial diseases and pneumonia, when the horse is taken to bitterly cold climates, and it is one reason why they do not survive in cold places. Now certain observers have reported that tropical races of man have larger lungs than northern races of equal height. It is called the "large tropical lung." Other observers have reported that the large lung in colder climates is prone to become tuberculous, particularly if it is accompanied by a small heart which cannot supply enough blood. On the other hand, small lungs and those conjested by leaky mitral valves are said to be remarkably resistant to tuberculosis. All these things may help to explain why the negro, with his open nostrils, large larynx, trachea, and lungs is so often a victim of tuberculosis. Much, if not most, of his susceptibility is unquestionably due to poor food and unhygienic living, and under proper management he is just as curable as any other race, but after all his physique is a serious handicap. The prevalence of pneumonia in cold climatic races, when they migrate to hot places, seems to be due to loss of resistance from exposure to heat and may have no relation to the size of the lung. At least, as before mentioned, there is no other explanation for the prevalence of hot-weather pneumonia.

The shape of the head is one of the most persistent of racial characters, appearing for thousands of years unchanged in spite of very wide migration. It proves the existence of an intruded Asiatic (Alpine or broad-headed) race in Europe since the bronze age or slightly before, and conversely it proves that the long-headed or Eur-African race has sent, since prehistory, many tiny streams of migrants all over Asia, where they can now be recognized from India to Japan. It is the main reason why more than one anthropologist is convinced that there have been two branches of the human race, Asiatic, or broad-headed and Eur-African or long-headed. The former is found around the Pacific ocean and the latter around the Indian Ocean. The two separated from their common ancestral stem at the very beginning of human evolution or shortly before in the anthropoid stage or perhaps a little earlier still. There must have been a remarkable difference in the two situations to make a long head, long face, and rather slender body fittest for one, and a broad head, broad face, and stocky build fittest for the other. It almost inclines one to believe that the European type was a tree or forest resident, and necessarily slender, while the Asiatic was a plains type needing more bulkiness. Be all this as it may, the general impression seems to be that the conditions have long passed away and that the two head shapes are now immaterial but persist through organic inertia as harmless characters. Even the western anthropoids are still to some extent long headed and the eastern broad headed.

There is reason to doubt this old idea, and to believe that head shape is of some benefit or disadvantage, as the case may be, but which is so slight that it requires some centuries or even millenniums to make a noticeable change in type by survival of the fittest variations among immigrants. England, for instance, is markedly mesocephalic in spite of the fact that nearly all the types which peopled it were very long headed. The round barrow race was round headed, to be sure, and might have reduced the long headedness by intermarriage, but there is reason to believe that head shape is a unit character which does not blend but appears unchanged in offspring—some long headed and some reverse. Boas of New York thinks he sees a similar phenomenon in the descendants of recent immigrants in the United States, though his facts, reasoning, and conclusions have been very strongly combated by equally able anthropologists. The medical side of the matter lies in the discovery of facts which would indicate a difference in adjustment of the two types here. In Europe the broad-headed type has not seemed to maintain itself as well as the autochthonous long heads, though this might be due to slightly higher average intelligence of the long heads. It is all too slight a matter for practical purposes, though there might be unexpected developments and it is not wise to neglect the study much longer.

The colon is still under discussion. It may have been of importance quite recently in our evolution, and its large size indicates some vital use, probably as a secondary stomach for the bacterial digestion of the rough, coarse, uncooked foods of primitive people. The assertion has been made that lower races which still subsist on coarse foods have much larger colons than civilized man and that the organ contains a profusion of bacteria for the digestion or at least the partial softening of the cellulose coverings of grains and seeds which may have escaped thorough mastication. The evidence in support of this opinion is not ample enough for acceptance, but the theory explains why lower races can thrive on foods which cause disease in the higher. Conversely there is some evidence that when lower races are fed on the more concentrated civilized foods, they suffer from diseases of the digestive organs and are not only lowered in vitality thereby but have their lives shortened.

Whatever the use of the colon may once have been, it is now of so little importance that it can be removed with no appreciable effect upon the general health. Metchnikoff of the Pasteur Institute and Sir William Lane of London independently came to the conclusion that our change of habits and diet had not only rendered the colon useless but an actual detriment to well-being, health, and life. The alleged involution which the organ has already undergone in civilization is certainly in favor of their conclusion, for, as before explained, useless organs do not diminish and disappear unless the new environment makes them harmful enough to hamper one in the struggle for existence; in which case, those men whose colons have varied in the direction of smallness are the fittest and survive in greater numbers. Nevertheless some very able anatomists and physiologists are in violent opposition to the conclusions of Lane and Metchnikoff and assert that if the organ were as harmful as these two scientists assert, it would have dwindled to a harmless size long ago, because under such circumstances involution is an exceedingly rapid progress. It is claimed that important bacterial digestion still goes on in the colon and that it is large for the express purpose of delaying the movement of the undigested mass, and that an important part of absorption takes place in the colon during this delay. It is acknowledged that these uses are not vital and that we can exist without them, and also that it is far better to have no colon at all than a diseased one. The quarrel then is a mere academic one, and has no practical bearing, for all seem to be in agreement with the main proposition, that in civilized races it is occasionally necessary to remove the colon or put it out of commission by "short-circuiting" the small intestine to the pelvic colon. It seems, however, that the arrested races and subraces do not suffer from such diseases to anywhere near the extent that the higher do, yet here we are on uncertain ground, as there are no accurate vital statistics to enable us to make comparisons. Whether an alleged large colon is partly responsible for the excessive negro death rate in the United States is very questionable, but the matter should not be ignored. The negro death rate from nephritis is 170 in the registration area of the United States and the white rate 95, and Lane claims that nephritis can be caused by toxic absorption from large sluggish colons.

Metchnikoff has studied the disharmonies which exist in man as the result of persistence of organs or tissues evolved for prior stages of our evolution, but which have become useless or harmful in the upright position or in the new environments created by social life. Some of these disharmonies are more pronounced in civilization than in savagery and these are legitimate subjects for investigation by medical ethnologists—the rest belong to medical anthropology.

Skin pigmentation has attracted more attention from ethnologists and physiologists than any other racial character because a tribe which has been long isolated invariably take[s] on a [illegible] is the same in all its members [illegible] of adjacent tribes. [illegible] fication and it has also been [illegible] proof that peoples of uniform [illegible] and are real "races." Closer investigation often shows that in other respects there are great differences among the members of a [illegible] nation, and that it is generally [illegible] several types, showing that there have been many immigrations. The word "race," then, has almost lost scientific value and is becoming [illegible] of the difficulty of finding one, or of telling what it is. The constant movements of population which have been going on by individuals or groups since man appeared have caused an enormously complex mixing. We find, therefore, that the same types occur in every nation of northwest Europe.

Since a mixture of types which is long isolated, takes on a peculiar more or less uniform coloration, it is proof that the unfit complexions have been fatal. Proper pigmentation is then a very vital matter, as it is of survival value. Mention has already been made of the partial disappearance of blonds from the Canadian French and their complete elimination from Louisiana Creoles, but as the process is a very slow one, requiring many generations, it has never been noticed. In fact few of us have any idea as to the complexions of our great-great-grand parents, and if all the blonds had gradually disappeared in the course of a couple of centuries, it would not have caused comment. Nevertheless, measured by the geological ages required for the evolution of animal forms, the evolution of color is exceedingly rapid. Moreover, a process which causes such marked change of type in a century or two must also cause noticeably greater morbidity and mortality of the unfit in one or two generations, as proved later. Complexion, then, is no guide to purity of race, because it is easily changed by change of environment—not that the climate changes each individual to the common tint, but because the best variations survive and the worst perish. Thus there is a remarkable uniformity of complexions among the descendants of numerous types which have invaded the Japanese Archipelago and now constitute that nation, although one can detect differences upon critical examination. At any rate there are no blonds and if there had been any among the long heads who probably arrived in the neolithic age, and possibly came all the way from Europe by easy stages, they have disappeared so long ago that there is no trace or tradition of them, beyond the surviving habit of picturing ancient upper types as having white skins. On the other hand, the Asiatic broad heads who invaded Europe were undoubtedly as swarthy as present-day Siberians, yet the darkest of them were so greatly out of adjustment and the lightest so much better fitted, that the Alpine "race" has actually become white. Indeed it was only comparatively recently that ethnologists proved on other grounds that it did come from Asia.

There is no longer the slightest doubt that the chief function of pigmentation is to protect the underlying protoplasm from damage by excessive light. There are also other causes for its evolution—as a provision against overheating for instance—but the main purpose is to keep living substance in the shade. Innumerable experiments and observations have shown that, without a single exception, every kind of light or ether vibration is lethal if it is sufficiently intense. It has recently been shown that Röntgen rays and the shortest ultra-voilet rays have a wave length much smaller than the diameter of a molecule of protoplasm, and that their effect is therefore intramolecular. They can disrupt this molecule without disturbing its rate of vibration. That is, the actinic effect does not alter the temperature. Infra-red rays, on the other hand, are longer and are able to

change the temperature by altering the rate and amplitude of the molecular movements.

We have long used strong sunlight as our most reliable disinfectant, and that process, so wholesome to us by destroying our microscopic enemies, has created the false popular impression that light is not only harmless to us but an actual benefit no matter how strong it may be. Yet so harmful is light to every form of living substance, that there is a continual elimination of those insufficiently protected. The survival of those with enough pigment thus creates a uniform pigmentation in all the individuals of a local species or variety.

The rule is universal in all plants and animals that the living protoplasm is guarded by some device or habit whereby it is never exposed to light of injurious intensity. In plants, the active cells are under the bark or in the roots in complete darkness and those in the leaf are protected by the green chlorophyl or by hairs or other contrivances. The light is used to break up the carbon dioxide of the air and if the rays are too strong they break up the protoplasm also. Hence the feebly protected shade-loving plants promptly perish when exposed to strong sunlight. For instance, the shamrock, which is fitted for the feeble sunshine of Ireland, will not live when transplanted to lands where the light is stronger.

Without any exception, every species of animal has a light screen such as hair, feathers or skin pigment, sufficient in amount to keep out the light to which it is daily exposed. In such cloudy places as England survival is possible with very little pigment, as in the white-skinned farm stock. Even in them there is sufficient skin pigment of a yellow or reddish color for the amount of light they encounter, but they never flourish when taken to lands of strong sunshine. Where there is much light, the animals must have much pigment, and in the lightest countries we find the darkest animals. Almost all the black animals live in the tropics. Even in the arctics where the snow glare of the summer is very intense the surfaces exposed to light, such as the tip of the nose and the retina, are jet black. If tropical animals such as white ants or the white larvæ of many insects, have no pigment at all, they are carefully housed in darkness. A white ant dies in a few seconds if exposed to the direct rays of the tropical sun of noon time, and the naked young of rats will die in a few minutes.

Although every kind of ray is lethal if strong enough, the injury increases with the frequency of vibration. The slow infra-red rays have practically no effect nor do the red, but as we approach the violet the injury increases and in the ultra-violet it is exceedingly serious. Permanent blindness has resulted from a very short exposure to strong ultra-violet rays and insects are killed in a few minutes. Röntgen rays and the very short gamma rays which are emitted from radium have similar effects, but the exposure must be longer, as they are not so intense as the ultra-violet we can generate by means of some kinds of electric lights.

The rule seems to be, that, if of little intensity, the short rays stimulate, in moderate degree they exhaust, and if very strong they actually disrupt the protoplasmic molecule without causing any rise of temperature. These, then, are the rays which do the most harm to us and which must be excluded, and as a fact it is found that the denser the pigment in man's skin the more efficient is it in excluding ultra-violet and Röntgen rays. As a general rule, men are pigmented in proportion to the intensity of the ultra-violet in the lands which evolved them—the Arab in the hot desert, the Eskimo in the fierce snow glare and the Apache Indian on our sunny plains, need about equal amounts of protection and they have evolved about equal amounts of pigment through selection of the fittest and death of the rest. The Amazonian Indian needs more and is nearly black, while the forest tribes of the northeastern part of the United States needed less and are nearly white.

Anthropologists were at first quite reluctant to accept this generalization, because migrated types persist a long time in climates where they have enough pigment or so nearly enough that the damage is immaterial. Then, also, people with much pigment will last longer still in places where there is little light. Our negro is surviving longer than the very blond immigrants and the two types, existing in a land which evolved the complexions of the Indians, had given the impression that pigment had no use at all. The perpetual migrations of men are followed by an equally perpetual elimination of the least fit, and in a mixed population we will always find that some types have greater mortality and morbidity than others—a matter which medical statisticians are just beginning to note and explain.

As above mentioned, intense infra-red or heat rays are just as harmful as any others—perhaps more harmful. All kinds of protoplasm have very definite temperature ranges, the upper death point being only a comparatively few degrees above the optimum. Some kinds are promptly killed by a temperature only a few degrees below the optimum, though the majority of forms can stand a great reduction for a limited time. As a universal rule, then, organisms perish when the temperature of the environment rises only slightly above the optimum, unless some means are taken to reflect the external heat and radiate their own surplus. As this is an exceedingly important matter in medical ethnology, which explains many facts as to "racial" diseases, and also points the way to rational therapy, the subject must be further investigated by physiologists.

An animal, which, by a happy variation, has developed some kind of a defense against overheating, will survive a hot period of weather which kills off all the rest by overheating. In the case of the higher mammals, these defenses must be exceedingly efficient, particularly for the nerve cells which are destroyed by a rise of temperature of only a few degrees. The superficial tissues may safely be reduced or raised several degrees, but the brain cells are disturbed by a rise of only one degree, and destroyed, in time, by a fever of six or eight degrees, while a rise of ten or twelve degrees, as in sunstroke, is fatal in a time counted by minutes. Hence in consequence of the survival of those best fitted with temperature regulators, there are many complex mechanisms for keeping the blood temperature uniform.

Color is an important means of regulating heat. The darker the color the easier does it absorb external heat rays from a hotter source or radiate internal heat to a colder environment. Hence the blackness of tropical animals is of immense assistance in keeping them cool in temperatures which are below body heat. The air temperature where black wild animals thrive is never over 98° and rarely over 90°; but may be as low as 60° or even less in the highlands. But these animals cannot expose themselves to a higher heat than that of their bodies, for they will then absorb too much and die of thermic fever. Hence they are nocturnal in habit and hide away in the water or in cool shade in the day time. Similarly the savage negro is nocturnal or at least shuns the midday sun, and he is most comfortable in his natural temperature between 75° or 80° and 98°, but he cannot stand a higher external heat as well as a white man. He has never maintained himself in the hottest climates. A hot fire-room will give anyone thermic fever in time, but the negroes succumb the soonest and furnish most of the victims on board ships. Similarly dark brunettes furnish proportionately far more cases of thermic fever than light blonds in the same conditions of high heat, but in temperatures lower than 98°, the brunette may be healthy and comfortable by

radiating heat where the blond is uncomfortable and is sickening from inability to radiate.

Haldane (*Jour. of Hygiene*, vol. v, 511–512) found that the rectal temperature did not rise until the wet-bulb thermometer was over 88° F., above which point it rose rapidly irrespective of humidity. For a man at work, the critical wet-bulb temperature was 85°, but if the air was moving at a rate of 170 feet a minute a wet-bulb temperature of 93° did not cause a rise of rectal temperature. That is, white men must have movement of air to carry off surplus heat by evaporation of perspiration in the range of air temperatures in which the negro is healthy with no air movement. It explains the fact that white men can last a longer time in tropical places having constant breezes day and night. Our hospitals, then, must be cooled in summer or the air kept moving, and experience so far shows that the death rate is thus lessened, particularly in all bowel infections, respiratory diseases, and malaria, but negroes must not be put in such wards. This matter of temperature range is a very important practical part of ethnic medicine in America. In hot places, white men swelter in rooms where dark ones are comfortable, and, if sick, will die where negroes recover.

In cold temperatures on the other hand blondness or rather a light-colored skin as in the yellow northern Asiatic races is a great advantage as it radiates less, while blackness is a fatal disadvantage as it radiates so freely as to chill the body. Negroes in cold countries require more clothing and warmer houses than white men, and escape the cold by indoor employments. The black man also suffers more from frostbite, chilblains, and rheumatic and other diseases having some relation to cold. Hence by survival of the fittest, a light skin is found where there is a cold and hot season; but where there is also some light to exclude, it takes a yellowish or reddish tint, and where there is little light the true blond is fittest, as in the northwest corner of Europe. The blond nordic type is perfectly comfortable in the cold and can stand a short hot summer, but he deteriorates when he migrates to sunny climates, whether they be cold or hot.

Complexion then seems to tie a man to a very restricted environment and his line will eventually perish if he gets out of his light and heat zone. It might take some centuries to cause misplaced migrants to disappear, but in the meantime they deteriorate and furnish cases of disease which are not found among the adjusted or among their kinfolk at the ancestral home. This is perhaps the most important part of medical ethnology and climatic therapy, particularly as the whole American nation is composed of migrants, all of whom are more or less out of their proper environment and who suffer from certain diseases far more than European white men or American Indians, and who conversely may de saved from other diseases more prevalent in their ancestral home.

The position of the hair of the head is proof that it has survived in that particular spot as a shade to the underlying cerebral cells. It exists even where the external temperature is very high and we would presume that overheating would result. It is not vital as a protection from cold except in great extremes, as perfect health is possible when the head is nearly or entirely bald. In very hot climates the hair is wavy or kinky to make it stand up from the head to prevent overheating. This device probably also increases the shade and is an additional guard against both light and heat rays, though the main effect is unquestionably the exclusion of light. Kinkiness of hair was evidently evolved very early before primitive man had sense enough to protect himself by a head-dress. It has therefore never been evolved in American Indians in the tropics, who also have arrived too recently for such an evolution. Pathologically, the cross-section of the hair [illegible] since we universally [illegible] and can cut the hair short.

An effort has been made [illegible] that sweat glands are more numerous [illegible] in the natives of hot climates than in those from cold, and there seems to be some evidence [illegible] At any rate, the evaporation of perspiration [illegible] important means of disposing of body heat.

"Heat cramps" is the only condition definitely proved to be due to excessive perspiration [illegible] hot fire-rooms of ships. The symptoms [illegible] as when the serum of the blood is drained off in cholera, contraction of all the muscles, dyspnea, suppression of urine, and perhaps [illegible] Death is very prompt unless the fluid is restored to the blood. Our naval surgeons have never been given enough credit for their magnificent work in discovering how to cure these desperate cases almost miraculously by intravenous injections of physiological salt solution. The uremia following the suppression is not the cause of the cramps, but both follow the high specific gravity of the blood due to the failure to drink enough water to restore the balance during excessive perspiration. It is possible for anyone to suffer from this condition, but negroes succumb soonest of all and white men resist longest. The negro absorbs more heat under these conditions and perspires more freely and he may develop fatal heat cramps from this partial desiccation long before the body heats up. Indeed some of the cases have subnormal temperature, though it is quite possible for the condition to be complicated by real thermic fever. It is not yet determined whether the alleged greater profusion of sweat glands in the negro is a factor predisposing him to heat cramps from excessive perspiration in the unnatural conditions of high external heat.

It is quite likely that while brunettes suffer from excessive perspiration more than blonds when the external temperature is over blood heat, blonds suffer more than brunettes in lesser temperatures. In the latter case the loss of water rarely if ever goes to the point of causing cramps or suppression, but there is recent evidence that the higher specific gravity and viscosity of the blood is one of the causes of cloudy swelling of the kidney cells and that chronic parenchymatous nephritis results. Certainly the hotter a country, the more common is this form of kidney disease and it is more prevalent among migrants from colder countries than among natives. Moreover there is some evidence that blonds in hot places suffer more than brunettes from nephritis due to this cause. Indeed the irritation of thick blood may be more potent to produce the cellular inflammation than the usual causes in colder countries.

In 1906 Scandinavians in Boston had the lowest rates for nephritis and heart diseases, as though they were more fit to live there than the other races, but the amount of parenchymatous nephritis is not known. These ethnic studies prove that we have not sufficiently emphasized the necessity of drinking much cool water in our tropical summers.

Since the action of light is at first stimulating, then exhausting, and finally lethal, we find that northern types recently arriving in the tropics experience very marked exhilaration, all their functions being performed far better than normally. This feeling of wellbeing conceals the damage, leads to undue exposure and hastens the stage of exhaustion, which invariably comes on, sooner or later. It is exactly the same as neurasthenia from any other exhausting causes, and the heat of the tropics as well as the repeated infections undoubtedly contribute to the result. That light is a potent cause is proved by the fact that it appears in cold light countries also and that blonds suffer more than brunettes.

Some years ago the writer called attention to the disease under the name of "tropical neurasthenia," and though the facts were at first denied, the condition is now recognized quite generally. It would be far better to have called it "actinic neurasthenia" to emphasize the fact that it is largely due to light, although aggravated by heat. Since blonds suffer from inability to radiate heat in the usual tropical temperatures, 80° to 95°, they are at a double disadvantage and furnish far more cases than brunettes of exhaustive states of the brain and nervous system.

The acute or fulminating form of actinic neurasthenia is still called "heat exhaustion," though it is now quite widely recognized as due to light. The condition is allied to shock from mechanical traumatism, indeed the nerve-cell changes resulting from the action of any of the short rays—light, ultra-violet, radium, and *x*-rays—are of the same order as those due to traumatism as described by Crile. "Heat exhaustion" is shock and has nothing in common with thermic fever or sunstroke with its high fever, bounding full pulse, more or less coma, dry skin, and often convulsions. Sufferers from actinic shock are conscious as a rule, have a normal or subnormal temperature, weak, thready pulse, wet skin, and extreme weakness and relaxation of all the muscular tissues. Minor forms of it result from exposure to strong electric light where there is almost a complete absence of heat, and in lower animals we can experimentally produce all grades of it up to the cases of prompt death. In man sunlight is never strong enough to kill. Blonds suffer from this condition more than brunettes, indeed I do not recall any reports of negroes suffering from pure "heat exhaustion."

When there is enough sunlight to do harm there is generally also a dangerous degree of heat, and this fact has led to the impression that heat was the cause of all the untoward effects of excessive sunshine. Again, the three conditions of thermic fever, actinic shock, and heat cramps may be present in various degrees of severity. There is then an infinite variety of cases with or without one or more of the characteristic symptoms of a pure case, and we had no way of unraveling the tangle until the recent inventions of ultra-violet electric lamps and the discovery of radium and *x*-rays proved to us that cold light itself caused typical "heat-exhaustion," and could be lethal from the molecular destruction.

People whose nerve cells have been damaged by heat and light must necessarily have suffered injury to other tissues also. Hence we find that blonds have more sickness from other diseases than brunettes in the ordinary degrees of tropical heat, and wherever the light is excessive. The eye naturally is the organ most affected, and we find that all the conditions due to glare are worse in blonds than in brunettes, such as night blindness from optic paresis, various grades of conjunctivitis, retinitis, and optic neuritis. The skin of blonds may suffer from lowered vitality differing only in degree from the sluggishness of all the tissues surrounding an *x*-ray burn. Not only may the pus infections be severe but there is much evidence that ordinary skin cancers as well as those following *x*-ray injury are more common in blonds than brunettes. Several observers have concluded that light and ultra-violet in the unprotected are almost as potent predisposing causes of cancer as are *x*-rays. The Italians in Boston have the lowest death rate from cancer, while the highest rates are among those from the northwest corner of Europe, the Irish being the worst, and the Scotch next.

Quite recently, attention has been called to the cases of photophthalmia arising among summer visitors to the seashore and caused by sea-glare. They do not occur in those who have sufficient retinal pigment nor in the blonds who are careful enough to wear darkened glasses.

The worst grades of photophthalmia are found in those who have been exposed at short distance, for only an instant, to the intense light of short-circuited electric wires carrying heavy high-potential currents. There is intense ciliary pain several hours later and lasting all night. Blindness may result. It is of course worse in the blondest.

Rufousness has yet to be explained. It was once supposed to be an ethnic character developed in some restricted locality as an advantage and that it has spread by migrations and now persists merely because it is not sufficiently disadvantageous to cause elimination of the type.

Recent observations in a restricted locality in England have shown that rufousness is invariably hereditary and never arises as a new mutation. It is a permanent recessive character. How it arose originally in such families is of course wholly unknown. It does not seem to be a disadvantage in northwestern Europe and it does not furnish any more extremely nervous, fiery, unstable types than the rest of the population. The case is different in those who migrate to lighter countries as in America. When tuberculosis attacks the rufous in the United States, it is rapidly fatal, particularly among the Hebrews. The type disappears as a rule from American families.

Anthropologists have long known that as a rule the dwellers in European cities are more brunette than the surrounding urban population, that city families tend to die out, and that the population is kept up by a constant flux from the country. Dr. F. C. Shrubsall of London has shown by very extensive statistics that in each locality, certain diseases show special affinities for certain types of the population (*Brit. Med. Journal*, Dec. 24–31, 1904, and *St. Bartholomew's Hospital Reports*, 1903). As to London it is found "that adult hospital patients as a whole are slightly fairer than the population within the sphere of attraction of each hospital," "that with each successive generation of city life the fair element sends an undue proportion of its members to the hospitals," "that child patients are markedly fairer than the children in the districts around the hospitals" and "that diminution of stature and increase of brunette traits are almost certainly progressive with increased heredity of an urban environment." In London blond traits are associated with acute rheumatism, heart disease, tuberculosis, and malignant disease, while the brunettes suffer unduly from nervous diseases, pulmonary tuberculosis, and malignant diseases. There is some evidence that tallness goes with the blond group of diseases and short stature with the brunette. In the British Islands as a whole there is also a relation between type and disease. Similar facts have been brought out on the Continent. Shrubsall concludes that the physical difference between city and country populations is due to the process of elimination of the unfit by disease.

There seems to be fair agreement among anthropologists that blondness was evolved on the continent and is an importation into the British Islands—indeed it was the prevailing type in the last invasions. It is therefore the least fit and is being eliminated in the most southerly parts, but the process is so slow that it was not noticed until the famous anthropologist, the late Dr. John Beddoc, discovered it by the most painstaking survey many years ago. He showed that the brunette types driven eastward by the blond invaders are now returning and becoming the prevailing type. In the far north where the conditions more nearly resemble southern Scandinavia, the center of blondness, the blond invading type is probably a permanent fixture in rural surroundings. In the cities of Scotland the reverse is found to be the case. Dr. David MacDonald has found in Glasgow (*Biometrika*, July, 1911) that "in the various gradations between the extreme dark and extreme

fair types, the closer the type approximates to fair, the less recuperative power it has and the less resistance it offers to the diseases."

The articles of Shrubsall give many illustrations of the diseases among misplaced races, and also refer to the very extensive continental literature on the subject. In America the matter has scarcely been touched since Baxter's great work on the statistics of the Provost-Marshall-General's Bureau, Washington, D. C., showing the relation between type and disease in the northern army, 1861–5.

Dr. J. S. Mackintosh of London has independently found that environment has an enormous effect upon types out of adjustment to the climate. His great contribution to the subject is his discovery that the big nordic blonds cannot stand dampness or confinement. They must have large open places and a dry soil, though they seem to thrive when the humidity of the upper air produces a maximum of clouds, to protect from excessive light. He mentions the western kinds who are an Aryan-speaking remnant of the blond, blue-eyed, long-headed invaders from the north, but the climate is dry and cold, the summers not too hot, and the country is mountainous. The same phenomenon of blond survival in the mountains is seen in this belt all around the world—our southern Alleghanies, the mountains of northern Spain, northern Italy—but everywhere as far as known there is a dry soil. Even in Sweden the blonds are largely in the uplands and brunettes on the coast. The damp-soil districts of England are solidly brunette, and if a blond wanders into them for residence he suffers unduly from catarrhs of the respiratory and alimentary tracts. The reason for this is not known, though it is unquestionably racial and due to some other character evolved in the dry-soil, cold, cloudy highland districts of Scandinavia coincidently with the blondness.

Mackintosh, who is a very keen observer, finds that the blond demands large open spaces. He calls attention to a remark by Tacitus ("Treatise on the Situation, Manners, and Inhabitants of Germany") that the German "villages are laid out, not like ours in rows of adjoining buildings, but everyone surrounds his house with a vacant space . . . . ." Even the villages were scattered and there were no cities. In America, we find that our tenements are largely occupied by the brunettes from the home of Tacitus, and that the northern Germanic types are moving to the open suburbs like their prehistoric ancestors. Moreover, as in Sweden to-day, the blond is best in the highlands and in all our hilly cities we find the lower the level the more brunette the people. This phenomenon is universal in continental Europe—mountaineers are more blond than the inhabitants of the surrounding plains. The practical importance of this lies in the fact discovered by Mackintosh and mentioned in the numerous articles (see *Clinical Journal*, Aug. 9, 1911, and *British Med. Journal*, 1910) that the misplaced blond suffers a lowered vitality predisposing him to disease of all kinds.

We instinctively turn toward a vacation place which makes us comfortable. All Americans like to go to Europe to escape our subtropical summers and to live where our types were evolved and where we are comfortable because we are adjusted. The blonds are showing a tendency to resort to high-level recreation grounds and the brunettes to the low level or seashore both here and in Europe. Even in occupations we see this same tendency. The tall blonds are failing in factory and shop because of the confinement, but are flocking to outdoor employments. The London soldiers and policemen are overwhelmingly light-eyed and yellow-bearded. In American cities there is a tendency that way, because stature is an important item in selection, but the excessive light and heat of summer modifies the process, as the blond is at a disadvantage. Street-car motormen are largely of [illegible] is essential, but there [illegible] this. Similarly European sailors are overwhelming blond, from the [illegible] an inherited seafaring [illegible] cities I have visited, the street workers are blonder than the [illegible]

Very high altitude causes so great a physical change to adjust a race to it that [illegible] for low levels. The increased mortality of mountaineers who go to the lowlands [illegible] statistics. The opposite is also true. Lowlanders cannot stand permanent residence in the mountains. It is quite a common thing for people to be driven out of our Rocky mountains on account of "nervousness," and it has also been known that pneumonia has a very high case death rate. In certain places, Mexico and Montana, for instance, it has become the custom to put a pneumonia patient on the first train after the diagnosis is made and send him to sea-level. The neurasthenia of high altitudes [illegible] to be worse in blonds than in brunettes. We are justified, therefore, in blaming excessive light for the nerve irritation, at very high altitudes above the cloud line, particularly as the condition is not found in lower mountains where the cloudiness makes an ideal environment for blonds.

In the central plateau of South Africa the matter was carefully investigated on account of the charge that cross-country runs were harmful for school boys, and the amazing discovery was made that the majority of school children had abnormal hearts. The red blood corpuscles are increased in number and the viscosity of the blood is also increased. The greater arterial friction, therefore, causes undue heart pressure, hypertrophy with subsequent dilatation, and the long train of symptoms going with this condition. Present-day mountain types, such as the Thibetans, have become adjusted through a long process of elimination, and selection. There must be other conditions which unduly affect lowlanders, who migrate to high levels, but the subject has not been given the study it deserves. The erythrocytosis of elevations might be one factor accounting for good results in tuberculosis. The tissues are better nourished, as in the collapsed lung of artificial pneumothorax.

The 1900 census shows that there are high [illegible] rates in the United States in the high altitudes east of California and west of Kansas, all the way from Canada to Mexico. Another area of high rates is in the semi-tropical strip of land bordering the lower half of the Mississippi River and, with this exception, the lowlands seem to have less mortality than the highlands of the immediate neighborhood. That is, America is peopled largely by Europeans from lowlands who are more or less injured by elevation.

It is quite likely that we can explain some racial nervous matters on the principles laid down by Freud. When a race migrates to a new environment, there is more or less nervous strain in resisting new adverse factors to which it is not physically adapted. There must be more or less fear, such as we see when we take an infant for the first time into a noisy place from its quiet home. The adult suppresses these fears, and they remain in his unconscious ego, only to come out in dreams or the phobias of Freud's "anxiety neurosis." Races evolved in open country must have dreaded the forest as rock pigeons fear the trees, and *vice versa* forest animals all dread the open. Racial fears must remain in man as long as they do in pigeons. Now it is a curious observation of Mackintosh of London that claustrophobia, or the fear of closed spaces, is far more common in the Baltic type than in the rest of Europeans. Could this not be the escape of a racial fear which has been suppressed ever since this type of man left his ancestral free and open life? I [illegible]

to psychiatrists, as it might assist them very much in the psychoanalysis of their patients and in therapy too, for the treatment of a case of claustrophobia must be more effective in the open country and difficult in the confinement of a city sanatorium.

The tuberculosis death rate among migrants is probably our best measure of their fitness for their new surroundings. We are born free of the infection, but begin to acquire it as soon as we crawl about, and by the age of six to ten nearly all civilized urban children are actively tuberculous. The lesions seem to cause a tolerant immunity by perpetual autovaccination, so that we are not harmed by the immense numbers of bacilli we inhale throughout life, but we are not able to kill off all the bacilli of our own foci. These stand ready to spread when we lose health and resistance from other causes, and as a fact, practically every one does show signs post-mortem that the lesions have spread some time in his life, but were later cured. It is evident then that if a man is being constantly harmed by the climate, he will be so weakened that he will not be able to recover from a tuberculosis which has been made active by some other cause. The people most injured would be those from climates markedly different from the ones where they are residing.

The climate of Ireland differs markedly from that of any place in the United States except our extreme northwest coast, indeed there is no place in Europe which shows such contrasts to America. It has no extremes of heat, cold, light, darkness or dryness, and it is exceedingly humid the year round. There has never been any selection of those fit for the above extremes and as a result some types of Irishmen, who were evolved as the fittest for Ireland, are proving the unfittest for America. According to the twelfth census, the general death rate and the death rates from tuberculosis and alcoholism, for all over fifteen years of age in the registration area, are higher for those having Irish-born mothers than for any other division of the white population. The Bulletin of the Boston Health Department, May, 1912, shows that the same high rates prevail in that city, and later investigation in New York City by the health authorities show that the conditions there are truly alarming. In Boston, seventy per cent. of the excess from the ages of fifteen to nineteen is due to tuberculosis, though this percentage progressively lessens with age. In New York city in 1906, the Irish death rate from tuberculosis of the lungs was 476 per 100,000, or almost exactly double the rate for all classes.

In Boston the other causes of excess deaths of the Irish were pneumonia, heart disease, nephritis, cancer, apoplexy, and alcoholism. O'Malley of Philadelphia some years ago called attention to the excessive alcoholism of certain Irish families in Pennsylvania. In Boston in 1900, there were sixty-eight deaths from this cause of which forty-four were of persons who had Irish-born mothers. Now it is accepted as proved, that alcoholism as a rule is an expression of a profound exhaustion of the nervous system, and there is some evidence that it afflicts the blond Irish more than the brunette. That is, the types least fit for our sunshine are the ones most damaged by it. The small brunette Irishmen seem to do far better here, but there are no figures to prove it, only the statements of several observers.

The other people from the northwestern corner of Europe are adjusted to more heat and cold than the Irish, and are better fitted for the climates of the northeastern part of the United States. The Scotch seem to be an exception, for their tuberculosis rate is is nearly as high as that of the Irish. Those having less than the average are Swedes, English, Canadians, and Germans, but as these are generally possessed of more means, their relative immunity may be due to economic causes. Tuberculosis increases with poverty. Part of the high rate of the Scotch is also due to the fact that mountain people are injured in the plains. The Swiss had the highest tuberculosis death rate in New York City in 1906, though it came down in later years. Bohemians and Austro-Hungarians also had high rates. Italians have only a slightly higher rate than the average in spite of their notorious poverty and unhygienic and unsanitary habits. On the other hand, the Finns in New York City have as high a rate as the Irish, which is probably because their native climate is so much cooler than New York. The susceptibility to tuberculosis is greatly increased by migrating to a hot climate.

While the Baltic types are only slightly above or below the average as to tuberculosis in our northeastern section, they suffer dreadfully in our sunny West. From some places in a large area, with Chicago as a center, they have practically disappeared from tuberculosis, where they were once very numerous. Lithuanians have furnished an undue number of consumptives in Chicago. There is no question that this is partly due to insufficient pigmentation.

The Ghetto Hebrews of Europe have been undergoing selection for a thousand years, more or less, and by the elimination of the unfit are now so adjusted to city life that they have the lowest death rate from tuberculosis in Boston and New York of any other nationality. They are largely brunette and it is a notorious fact that when a blond Jew does become actively tuberculous the course is rapidly fatal. Statistics published a few years ago by the writer showed that blonds of other nationalities suffered more from tuberculosis than brunettes in our lighter climates, and this fully accounts for the way blonds have diminished in the older stocks. Selection has also eliminated the tall and bulky types from among the Jews, and they are now so unfit for life outside of the cities that few are able to take up farming or any other trade requiring great expenditure of energy or exposure to cold in outdoor labor. Indeed, so thoroughly has city life eliminated the big that the survivors are largely unfit for military service. Many do become soldiers, but the proportion is very small as compared to the peasants adjusted by greater stature to rural life.

The great prevalence of nervous disorders among Hebrews has been thought to be due to the accumulated effects of centuries of persecution. They have been alien intruders, so to say, and have kept aloof from the social organism from which they have obtained subsistence. They have actually lived on their wits while the natives lived on their muscular energy. None but the shrewd and nervous could survive such a life and their pre-eminent abilities today are therefore a result of selection. That type of man is everywhere subject to nervous disorders, largely neurasthenic in origin. Nevertheless, there seems to be a correlation between brunetteness and nervous disorders in the British Islands in the stock that has been there hundreds of millenniums and is perfectly adjusted physically to the climatic environment both urban and rural (Beddoc and Shrubsall). The explanation seems to be the lowered resistance due to poverty, for the brunettes predominate in the overcrowded areas and in the lowest economic classes and are therefore badly nourished. The well-to-do are more blond, better nourished and have less nervous disease except where they are hopelessly unfit for the climate. Not only do blonds have more nervous disease in the tropics, but they furnish a large number of cases in our South.

Shrubsall and others report that in northwest Europe the brunettes predominate among the tuberculous. This seems to be more marked the blonder the population, and is evidently due to racial unfitness as well as poverty. It is a very marked phenomenon in northern Germany and Scandinavia but less so in England. On our northwest coast I have been in-

formed that no Italian so far advanced in tuberculosis as to have bacilli in his sputum has ever been known to recover. He is unfit for this dark rainy land, but in southern California, where the conditions resemble those of southern Italy, the Mediterranean types furnish the highest percentage of cures. In New York City, the tuberculosis mortality for each nationality does not vary much from year to year as a rule.

It is not temporary and accidental, but a permanent vital phenomenon, constantly eliminating the unfit among the newcomers. The survivors should show marked differences in a few generations in the way of lessened mortality. In New York City, for instance, in 1906, with the sole exception of the French, the death rate from tuberculosis in each race was greater among the foreign-born than among those born of foreign parents. The difference in average age of the two classes is not sufficient to account for the difference in mortality, indeed it ought to act the other way, for the foreign born are more largely of an advanced age when tuberculosis is less common. The average death rate for all is 239, but in the native-born it is 207, and in native-born of native parents it is only 157—almost as low as the rate of those born of Russian and Polish parents, mostly Hebrews—135.

Baxter found that brunette soldiers in our civil war, who campaigned in our South, had less disease and were stronger, and that the tall and blond suffered unduly from tuberculosis. This process is making our lowland Southerners a race of brunettes of medium stature.

The blond mountaineers are vigorous, as the climate is like that of northern Europe, but the lowlanders are generally so lacking in energy and intelligence as to be evidently decadent and on the way to extinction.

An important part of medical ethnology is the study of the manner in which, by long-continued natural selection, a type will develop more or less immunity to certain diseases. Dr. G. Archdall Reid has been the leading worker in this field and in his books on "Alcoholism" and "Heredity" he gives a profusion of illustrations which conclusively prove that the longer a race is acquainted with a disease the less harmful it becomes. Measles, for instance, is exceedingly fatal to lower races which have never before been infected, but it has eliminated from civilized people nearly all those who cannot promptly develop antibodies to kill off the invading organisms. Only a very small percentage of the infected die of it in civilization. The same reasoning is supposed to account for the mildness of mumps, whooping cough, and chickenpox. On the other hand, the severity of scarlet fever and smallpox is explained on the assumption that they have been more recently evolved by differentiation from harmless organisms or from those which have taken on parasitic habits in lower animals and subsequently transferred their activities to man, such as the plague bacillus. Both gonorrhea and syphilis seem to be getting mild in civilized races and are mild negligible complaints among the Japanese. Indeed, in the great majority of healthy young Europeans, too, gonorrhea is a short self-limited disease, though in the non-resistant its ravages are terrible. Our genito-urinary specialists could give us exceedingly valuable ethnic data as to the types of men who have gonorrhea difficult to cure.

Tuberculosis also is a severe infection among savage races which have never been infected before, but it is now believed to be universally present in civilized races because all who could not develop antibodies to keep it in check have been killed off. It becomes active only in those who lose resistance from some other cause. There is considerable ground for the opinion that this evolution has occurred in the short time man has been living in houses, before which populations were too sparse for the infection to be carried from person to person, and the [illegible] life would have cured them if the bacillus were present. The organism probably [illegible] thence gave rise to the [illegible] scourge only after populations [illegible] lived in overcrowded [illegible] culminated with the dreadfully unsanitary conditions existing when the modern industrial era began in the eighteenth century, since [illegible] of the most susceptible has so cleared [illegible] that the annual mortality has been reduced to less than two per 1,000 in northern Europe. It still causes one death in every seven to ten according to locality, but as nearly everyone shows postmortem signs of having overcome a temporary activation of his lesions, we can assert that in about eight or ninety per cent. of humanity the infection is harmless. Moreover, these cures take place without special treatment, which never occurs with negroes and American Indians, in whom it is said to be invariably fatal, unless given special sanatorium treatment.

There is a suspicion that we gradually evolve an immunity against whooping cough in the same way as we do that against tuberculosis—that is, by too frequent inhalation of small numbers of attenuated bacilli, which gradually produce enough antibodies to render us immune. That is probably why the disease is so fatal to the young, the mortality being twenty-five per cent. in those less than a year old, and very fatal in the early months of life. The mortality quickly diminishes with age and in time we are wholly immune, though we may lose that immunity as in the case of tuberculosis. The varying mortality from whooping cough from race to race is probably due to the different periods during which the races of the world have had contact with the disease.

Alcoholism should be studied with the infections. Reid shows that races newly acquainted with it are very drunken, but that in time through the elimination of the susceptible a race becomes temperate. Among migrants, on the other hand, alcoholism affects those most out of adjustment. As before explained it is a symptom of nervous derangement, and it seems to be one of the ways in which natural selection unifies a type locally by eliminating the least fit. The bacchanalian orgies of the ancient blond Aryan invaders of Greece unquestionably hastened their decay and extinction, and possibly the same was true of the early Romans. The Irish in America have had something of the same kind of history, according to O'Malley.

The least fit for a place are naturally the least efficient. Their weaknesses finally disable them. They cease to be self-supporting and become public burdens or resort to parasitism of some kind. I find that in New York the blonds furnish an undue number of paupers, insane, and chronic offenders against property. The southern races of Europe predominate in crimes of violence, but they do not cause more crimes proportionally than in southern Italy a few years ago. It is a racial norm with them, but the crimes of the northern races here are largely an indication of racial decay. In northern Europe the conditions are reversed, as in the case of tuberculosis. In the blond areas, the brunettes are the most criminal.

The practical side of medical ethnology is self-evident, for it not only explains the "racial" differences in morbidity and mortality, particularly in America where so many types are so far out of adjustment that they cannot possibly survive permanently, but it also gives a hint as to the [illegible] management of individual cases. It is far more than medical climatology and more than what might be called medical anthropology or study of the [illegible] tionary differences between man and the lower animals.

Mackintosh has frequently found in England that

a patient whose physical type differs widely from that which characterizes the families of many generations of local residence not infrequently suffers from general ill health which cannot be improved by anything short of a return to an environment normal to him. He quotes Sir Wm. Bennett to the effect that he has found the city best for those consumptives who are physically adjusted to such a life. We in America, then, can save our patients much illness if we will observe their physique and determine whether lack of adjustment is a factor in the case. For instance, the writer knows of a very brunette man who is in excellent health in the sunny climates of our Southwest where he has mining interests, but his wife who is a bright blond suffers from the neurasthenic conditions so prevalent in that type in light countries. In a more cloudy climate where she is at her best, he suffers.

In selecting a place to send a patient for cure, convalescence, or permanent residence, we must choose one which resembles that which has evolved the type. It was a dreadful mistake to send all consumptives to Florida and we have ceased to do it, because of the bad results. It is equally wrong to send all to the northern mountains. Plains people should not be sent to the mountains or mountaineers to the plains, dark types to dark climates or blonds to the sunniest, thin slender ones to excessive cold or fat and bulky ones to very hot, northern races to southern climates or tropical peoples to high latitudes. Those needing travel will find the good negatived if they travel in a bad climate, but mere residence in northwest Europe for a while may do a world of good to one who has been damaged by our tropical summers. Indeed the annual summer exodus to Europe is attaining the proportions of a flood simply because people are finding out the good it does to return to our ancestral climatic homes.

In applying physiotherapeutic measures we must also be guided by the type of patient. We cannot apply cold or heat to all alike, for one man will be greatly injured by what benefits another of different physique. Much of the discontent with balneotherapy is possibly due to the failures following neglect of this precaution. A very hot room will have effects sooner in the very brunette, who will suffer harm if they remain too long.

In the application of light to the naked body similar precautions must be taken. It is found in the Swiss Alps, where such treatment for surgical tuberculosis is quite popular with a few physicians, that excess is very harmful, causing phosphaturia, nervousness, melancholia, prostration, and a psychosis—indeed all the conditions found in the tropics among Europeans who expose themselves unduly to the light and heat. Short exposures are found stimulating and may improve patients with mental depression, but the stimulation is liable to cause hemorrhages if the lungs are tuberculous. Moreover, the blonds do not improve under light treatment nor can anyone stand the strong summer sun in the Alps where the exposures must be given on mild days neither hot nor cold nor cloudy nor windy. Those who get the most benefit are the brunettes who take on a thick coat of tan which excludes the light, and even in them we get just as good results in cloudy climates and lower levels. Some of the best specialists in the Alps are bitterly opposed to sun exposure because of the harm it does in excessive amounts and because of the absence of proof that the light is the cause of any cures. They credit the cold rare air, rest, and food.

Medical ethnology is of great importance in America because all people of European ancestry are physically unadjusted to the climatic environments to a greater or lesser extent, and there has been an undue mortality from this cause. We can never reach the low morbidity and mortality rates of Europe where sanitation is cultivated, but we can improve matters greatly by studying the types which suffer the most from each class of disease. It will then be a short step to devising ways and means of avoiding the adverse factors by building up an artificial environment. The science seems destined to play a big part in future hygiene. CHARLES E. WOODRUFF.

Ethoxy-caffeine ($C_8H_9.OC_2H_5N_4O_2$) is obtained by boiling monobrom-caffeine with an alcoholic solution of caustic potash. It forms crystals which are soluble in hot alcohol, and less so in ether. It is used as a sedative in neuralgias and migraine. Dose, gr. i. to v. (0.06–0.3 gm.), in capsules or wafers.

R. J. E. SCOTT.

Ethyl Bromide.—*Hydrobromic Ether:* C_2H_5Br. This body is a thin, colorless, very volatile ether, of a strong smell and hot taste; practically non-inflammable; sparingly soluble in water, but freely so in alcohol and ether. It is prone to spontaneous decomposition, on exposure, and should be kept in dark-colored and well-stoppered bottles, away from the light. A yellowish tinge means decomposition, and a sample so discolored is unfit for use.

Hydrobromic ether affects the human system similarly to chloroform, with the special features that sensibility is deadened early, and that narcosis comes quickly and pleasantly, but without full muscular relaxation. The latter circumstance is a drawback, since often a continuing of rigidity and even of spasms into the stage of narcosis defeats the use of the agent as an anesthetic in surgery.

Hydrobromic ether causes fall of blood pressure, and, in overdosage, death, all after the manner of chloroform. It has been used as an anesthetic, given by inhalation of its vapor, especially in cases in which a momentary narcosis only is needed.

It is given similarly to chloroform.

EDWARD CURTIS.
R. J. E. SCOTT.

Ethyl Carbamate.—ÆTHYLIS CARBAMAS (U. S. P.), Urethane or Ethylic urethane ($NH_2.COO.C_2H_5$). This compound occurs in colorless tabular crystals, soluble in water, alcohol, and ether. It has no odor and but a mild ethereal taste, producing a sensation of coolness in the tongue. It is obtained by the action of ethyl alcohol on urea or one of its salts. Urethane operates upon the animal system as a quite pure, though not overpowerful hypnotic, without effect upon the peripheral sensory apparatus, and without untoward effects of any kind. It does not disturb the blood pressure, pulse rate, or the respiratory center; but, like all urea derivatives, it has a diuretic action. It is used in medicine for procuring sleep, and is found fairly efficient in the more tractable conditions of insomnia. Doses of gr. xv. (1.0) commonly suffice, but the drug may be required in two or three times this quantity, and such large doses have been perfectly well borne. It may be prescribed in simple aqueous solution. The remedy has also been administered by hypodermic injection. R. J. E. SCOTT.

Ethyl Chloride.—*Hydrochloric Ether,* C_2H_5Cl. Ethyl chloride is prepared by the action of hydrochloric acid on alcohol, the resulting ether being condensed at a low temperature. When maintained at a temperature below 50° F. it is a colorless liquid having an alliaceous taste and smell. Its specific gravity at 32° F. is .9214. It mixes with water, about one part in fifty, and with alcohol and ether in all proportions. Its boiling-point is 54° F., and above

this temperature it exists as a gas. As a gas it is exceedingly inflammable, burning with a greenish flame and evolving hydrochloric acid.

Following the introduction of ether and chloroform, it was one of the many compounds suggested as suitable for general anesthesia. Being very volatile it was easily administered and its anesthetic action was more rapidly procured. The anesthesia which it produced, however, proved to be very transient, and further experience as well as experimental work has shown that its action is accompanied by marked vascular and cardiac depression. Although strongly advocated by many, its employment never became general.

It is better known as a local anesthetic. Advantage has been taken of its rapid evaporation to utilize the intense cold produced, in dental and minor surgical practice, and for the relief of the pain of superficial neuralgia. It has been used with satisfaction for the extraction of teeth, for opening abscesses, for removing ingrowing toe-nails, and for similar painful operations, and has been found to give instantaneous relief in facial neuralgia, intercostal neuralgia, and sciatica.

The method of utilizing this property was made simple and easy by Monnet, of Lyons, who suggested the storing of the compressed fluid in small capsules and tubes, by which means it may be preserved without alteration for a great length of time. When the drug is required for use the point of the capillary tube is broken off, and the opening directed downward on the part to be anesthetized. These tubes have now been perfected by the addition of a screw cap which allows of any proportion of the contents being utilized, the remainder being preserved for future use. The heat of the hand is sufficient to raise the temperature of the fluid above its boiling-point, and a stream of the rapidly volatilizing fluid issues as a spray, and may be applied to any part. The tube should be held at a distance of eight or ten inches from the part, and the surrounding tissues protected to prevent excessive and needless destruction of tissue. The surface of the skin acted upon rapidly becomes blanched and devoid of sensation, and regains its normal state upon the removal of the spray. If the application is persisted in, the vitality of the part is destroyed and necrosis is the result. During the employment of the spray care must be taken that no flame shall be in proximity, on account of the inflammability of the gas.

BEAUMONT SMALL.

Ethyl Hydrocupreine.—This substance is a derivative of quinine, and its relation to that alkaloid may be seen in the formulæ of the following substances:—

Cupreine	$C_{19}H_{20}N_2OH.OH$.
Quinine	$C_{19}H_{20}N_2OH.O.CH_3$.
Hydrocupreine	$C_{19}H_{22}N_2OH.OH$
Methyl hydrocupreine	$C_{19}H_{22}N_2OH.OCH_3$.
Ethyl hydrocupreine	$C_{19}H_{22}N_2OH.OC_2H_5$.

Ethyl hydrocupreine was brought forward by J. Morgenroth as having a powerful, and possibly specific, influence on the pneumococcus. More recently it has been used with benefit in cases of pneumococcus infection of the external eye. R. J. E. SCOTT.

Ethyl Iodide.—*Hydriodic Ether:* C_2H_5I. This substance is prepared by distilling a mixture of alcohol, iodine, and phosphorus. It is a clear, colorless liquid (but becomes colored when the iodine is set free); it has an ethereal odor, and a pungent taste. It is soluble in about 400 parts of water, and mixes readily with alcohol and ether. As it decomposes when exposed to sunlight or to air it should be kept in well-stoppered bottles and [illegible] iodide has been used [illegible] bronchial asthma and [illegible] is fifteen to twenty [illegible] large iodine content. It [illegible] method of introducing iodine into the system, and that element has been found [illegible] minutes after inhalation of ethyl iodide.

R. J. E. SCOTT.

Ethylene Bichloride.—*Bichlorethylene, Dutch Liquid,* $C_2H_4Cl_2$. This body is a [illegible] fluid, smelling and tasting much like chloroform; volatile and inflammable; dissolving sparingly in water, and freely in alcohol and ether. Its only medical interest lies in its attempted substitution for chloroform, as an anesthetic which should retain the advantages of chloroform while free from its dangers. It is rapid and powerful in its action, and seems to operate much like chloroform; but it tends to paralyze the respiratory center before the heart. It is, however, very irritating to the throat. Administration, in mode and dose, is the same as that of chloroform.

EDWARD C[illegible]
R. J. E. S[illegible]

Ethylene Bromide.—$C_2H_4Br_2$. A [illegible] faintly brown liquid, containing 90.9 per cent. of bromine. The odor is agreeable and taste sweetish. Its specific gravity is 2.163 at 60° F. [illegible] F. it becomes a solid, forming crystals. It is insoluble in water, soluble 1 in 4 of rectified spirit, and miscible in all proportions with absolute alcohol and oils.

Ethylene bromide was introduced into therapeutics as a convenient means of supplying bromine in cases in which its use is indicated for a prolonged period. The advantage claimed for it is that it does not disturb the digestion, the skin, or the mucous membranes, or produce any of the unpleasant effects that the sodium and potassium salts are liable to cause. It has been usd in the treatment of epilepsy, delirium tremens, and other conditions in which the bromides are indicated, in doses of ♏j.–iij. (0.06–0.2) in capsules or emulsion. At one time its use as an anesthetic was suggested but it was found to be practically devoid of anesthetic action and, moreover, its inhalation has been followed by poisonous symptoms. T. L. S.

Ethylene-diamine $C_2H_4(NH_2)_2$ also known as diamino-ethane is a thick, colorless liquid, with an alkaline reaction, a caustic taste and an ammoniacal odor. It is freely miscible with water, and has the property of readily dissolving albumin. Hence, it has been recommended as a solvent for the false membrane in diphtheria.

Ethylene-diamine-trikresol also known as *[illegible] amine* or *kresolamine,* is a watery solution of twenty-five per cent. each of ethylene-diamine and trikresol. It is a clear alkaline liquid and is used as an antiseptic.

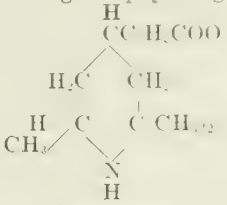
Ethylene-diamine silver phosphate is argentamin (see *Argentum*).

Mercuric ethylene-diamine sulphate is known as sublamine (see *Hydrargyrum*). R. J. E. SCOTT.

Ethylidene Chloride CH_3CHCl_2. [illegible] ethidene bichloride, is a colorless liquid resembling chloroform in its physical properties and also in its action on the system; but it is believed to be less depressing, and, therefore, safer than chloroform. It has been used as a general anesthetic for short operations but is not much employed [illegible] day.

R. J. E. S[illegible]

Eucaine.—There are two eucaines, called respectively alpha-eucaine and beta-eucaine. They are synthetic alkaloids, complex piperidine bodies, prepared expressly to serve as local anesthetics in the place of cocaine. The alpha-eucaine is no longer used, and the word eucaine, when unqualified, is now generally taken to mean beta-eucaine. Chemically the latter is the benzoyl derivative of vinyldiacetonalkamine. The salt used is the hydrochloride, and it is generally employed in a solution of from one to four per cent. strength in physiological salt solution.



Beta-eucaine

It is used as a local anesthetic, and details of its action and therapeutic use will be found in the article on *Anesthesia, Local* (vol. i., page 390).

As compared with cocaine, beta-eucaine hydrochloride is much cheaper, less toxic, does not decompose on being boiled and so is more easily rendered sterile, has no unpleasant after-effect, and gives rise to no "eucaine-habit." R. J. E. Scott.

Eucalyptus.—Blue Gum-tree. "The leaves of *Eucalyptus globulus* Labillardière (fam. *Myrtaceæ*) collected from the older parts of the tree" (U. S. P.). At the close of this article will be found some general information concerning the genus Eucalyptus. Attention is here restricted to the drug above defined. This species occurs in the province of Victoria, Australia, and in Tasmania. It grows to a great size, but is not nearly so large as some of the other species. The exhalations from the tree, where forests

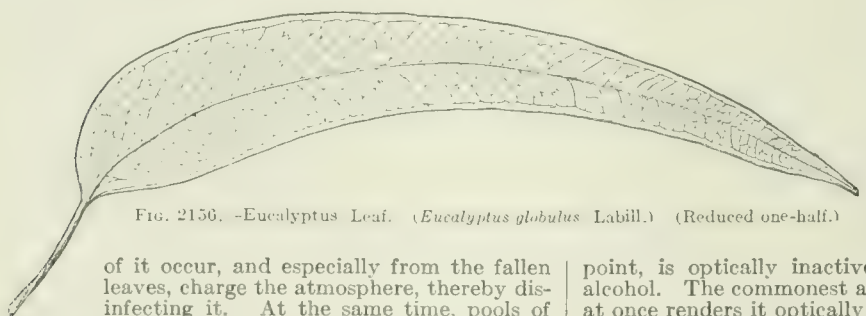


Fig. 2156. -Eucalyptus Leaf. (*Eucalyptus globulus* Labill.) (Reduced one-half.)

of it occur, and especially from the fallen leaves, charge the atmosphere, thereby disinfecting it. At the same time, pools of water containing the leaves are rendered uninhabitable for mosquito larvæ. This has suggested the idea of planting it in malarial regions, as about Rome, for a similar purpose, but it is doubtful if the experiment has anywhere been performed in a sufficiently thorough manner or upon a sufficiently extensive scale. It was an incorrect notion of this property of the tree which suggested its first use in medicine, that of a specific for malaria. In this direction it proved disappointing, but other important medicinal uses were found for it. The tree, when young, and the younger portions of it for some time after, bear leaves which to a great extent are wanting in the active constituent. These leaves are broadly ovate, heart-shaped at the base, little or not at all tapering at the apex, and comparatively thin. The official leaves (Fig. 2156) are fifteen to thirty centimeters (six to twelve inches) long by two to four centimeters (three-fourths to one and one-half inches) broad, lanceolate and tapering from near the blunt base to an acute tip, strongly scythe-shaped, and very inequilateral, entire-margined, very thick, leathery, smooth, strongly glaucous, and with a short, stout, flattened and twisted petiole. Against the light they are strongly pellucid-punctate. They are highly aromatic. It is not known how leaves grown in the several countries where the tree has been introduced compare with those of native origin, but some of them are known to be very inferior, and it is certainly a conservative and wise policy to accept only those of native growth.

Composition.—Besides their active constituent, about six per cent. of volatile oil, they contain wax, resin, and tannin. The medicinal properties and uses of the drug can be best considered farther on, in connection with those of the oil and of eucalyptol.

Oil of Eucalyptus (*Oleum Eucalypti*, U. S. P.) is defined as a volatile oil distilled from the fresh leaves of eucalyptus, rectified by steam distillation, and yielding, when assayed by the U. S. P. process, not less than fifty per cent., by volume, of cineol. It has a specific gravity of about 0.905 to 0.925 at 25° C., a characteristic odor and taste, and it dissolves freely in alcohol. Since the active constituent of the oil is *eucalyptol* (properly called cineol), the determination of the percentage of that constituent constitutes the proper method of valuation. With eucalyptol, there is pinene (from *E. globulus*) or cuminol (from *E. oleosa*), or the two oils may be mixed. Traces of several aldehydes may also be present. The optical rotation will also differ greatly in accordance with the source. The action of the oil, except for its being weaker and less regular, is that of eucalyptol. Phellandrene is its most common impurity, derived from other species of Eucalyptus.

Eucalyptol or *Cineol* ($C_{10}H_{18}O$) is defined by the Pharmacopœia as " an organic oxide obtained from the volatile oil of *Eucalyptus globulus* Labillardière and from other sources." The allowance of "other sources" is here not objectionable as in the case of the oil, for the eucalyptol will be the same no matter what its source. It is also the active constituent of oil of cajuput and of some other Myrtaceous oils, and occurs in santonica, rosemary, peppermint, and many other oils of this and of other families. It is liquid, colorless, with a characteristic odor and taste, has a specific gravity of about 0.925 at 25° C., boils at 176° to 177° C., crystallizes at freezing point, is optically inactive, and dissolves freely in alcohol. The commonest adulterant is the oil, which at once renders it optically active.

Action and Uses.—The action and uses of eucalyptol and of the oil must be considered first, as that of the leaves is not quite identical. Their special property among volatile oils (see *Active Constituents of Plants*) is their antiseptic and expectorant properties. As an antiseptic, eucalyptol ranks second only to oil of cinnamon, and this property increases somewhat as the oil ages. It is not markedly irritating to the skin unless the surface is abraded or the vapor is confined, but it is markedly irritating to mucous membranes, expecially to that of the stomach. As an expectorant, whether taken internally or by inhalation, it is both stimulating and antiseptic. Its antiperiodic, action is very similar in kind, but also very inferior, to that of quinine. As a poison it acts as a gastro-intestinal irritant, and as a paralyzant of the vital functions, especially of the heart.

The uses of this drug are all to be regarded as local; even when given internally, it is transported in the circulation to the seat of its action. Externally, it is

an excellent application to ulcers which require either disinfection or stimulation. For this purpose, a two- to five-per-cent. solution of the oil in alcohol may be employed, or a ten-per-cent. tincture of the leaves is sometimes even better, owing to the resin and tannin contained. The greatest value of eucalyptus is in the treatment of catarrhal conditions. Here the beneficial results are directly proportional to the need for stimulation and disinfection, and the reverse is true when there is already irritation or inflammation. Thus it is used topically, as well as internally, in gonorrhea and vesical catarrh, in low forms of dyspepsia, and in respiratory catarrh. Although slightly diaphoretic, it is scarcely useful in that way. Its antiperiodic powers are feeble, but it is often of use when the case is mild, and the surroundings are not continuously infectious.

In considering the properties of the leaves, we have to regard only the percentage of oil which they contain, and the fact that the amounts of resin and tannin, and the bitter taste, are sufficient to add their effects to those of the eucalyptol.

The dose of the leaves and of their fluid extract, the only official preparation, is ʒss. and ʒii. (2.0 and 8.0) respectively. The oil and the eucalyptol are given in doses of from ♏v. to xxx. (0.3 to 2.0).

The genus *Eucalyptus* contains between 125 and 150 species, almost all of Australia and Tasmania. They are for the most part large trees, rivaling in altitude the highest known, and form dense and vast forests. Their economic importance is of the highest. Their ability to withstand adverse climatic conditions permits of forestry operations where they would be otherwise impossible. Their timber is proof against the attacks of many destructive animals, and resists decay. Their astringent gums, described below, are of great importance. Many of the oils, though excluded from the uses above specified, as they contain no eucalyptol, are of importance in the arts. The trees are, moreover, highly ornamental.

HENRY H. RUSBY.

Eucalyptus Gum.—EUCALYPTI GUMMI. EUCALYPTUS KINO. A ruby-colored exudation, or so-called red gum, from the bark of *Eucalyptus rostratus* Schlecht, and some other species of eucalyptus. Sixteen species of eucalyptus have been named as yielding these gums, which are now very generally used in the place of our official malabar kino, this having become excessively scarce and high-priced. It is even true that the former is very commonly given where the latter is called for. The two are very similar indeed, this one occurring in grains or small masses, the fragments transparent and of a ruby-red or garnet-red color, somewhat tough and of a very astringent taste. When chewed, it adheres to the teeth and tinges the saliva red. Cold water dissolves from eighty to ninety per cent., forming a neutral solution, and it is almost entirely soluble in ninety per cent. alcohol. The properties and uses of this substance are identical with those of kino, and the dose is gr. ij.-v.(0.12–0.3).

HENRY H. RUSBY.

Eudermol, or nicotine salicylate, occurs in white or yellowish white crystals; it is freely soluble in water and alcohol, but it is generally used in the form of an ointment (one per cent.) in certain parasitic skin diseases. It is chiefly employed in veterinary practice.

R. J. E. SCOTT.

Euflagellata.—*Flagellata.* Mastigophora with one or more flagella. Many species are colonial. This subclass of protozoans contains many parasites. See *Protozoa.*

A. S. P.

Eugallol, or pyrogen [illegible] $(CO\,OH)_3$, is a dark [illegible] and in acetone. It is [illegible] cent. solution in acetone and [illegible] similar conditions.

R. J. E. SCOTT.

Eugenics. Eugenics has to do with the improvement of the human race by better [illegible] far as it has an end or goal to be [illegible] and a program for reaching it, [illegible] but this applied science must rest on certain ascertained facts, and the collection and analysis of these facts constitute the pure science.

The scope of eugenics includes, first of all, the study of the heredity of human traits, secondly, the study of human families, "blood-lines" or strains, and "biotypes" or elementary species, and thirdly the application of this knowledge to the improvement of the race by increasing the proportion of persons with the socially fittest desirable qualities through the best marriage selection, the high fecundity of the best stock, and selective immigration.

Heredity.—The study of the heredity of human traits entered upon a new stage with the recognition of the general principles that traits are to be studied one at a time; that inheritance is not from parents, grandparents, etc., and that traits, as such, are really, strictly not inherited at all. It was necessary to cast off a lot of rubbish and figures of speech which clung about the term heredity before it became the subject of serious biological consideration. As most persons are yet uninstructed in the modern biological viewpoint of heredity, it is necessary to elucidate this somewhat fully. And first a serious warning must be entered against the so-called biometrical school of heredity, which looks at heredity purely by the method of mass statistics. No biologist of any standing can justify the method of studying heredity of the statisticians, who, in the vast elaboration of statistical method, seem to be blind to the fact that biologists no longer use the language for which the biometricians are seeking precise quantitative expression, and their results, though quantitatively precise, have, once they are obtained, no biological significance.

For the biologist, then, inheritance is not from any person but from the germ cells; the germ cells do not contain the adult inheritable traits but contain some things (chemicals) that *determine* those adult traits. These may be called *determiners* (or differentials, as they determine differences). The reason for the resemblance between father and son is that both arise from germ cells that contain some of the same determiners; but it is quite as true that a father inherits his traits from his son as the reverse; it merely happens that in the father some of these determiners develop earlier in the history of the race; or in the son the same kind of determiner develops later. If, as is probable, the determiners are constantly doubling by fission, one cannot say the determiners of the fertilized egg that go to form the son are derived from those that go to form the father. The determiners in the embryo son are just as old as those that went into the father; in fact, a little older, as the race is older at the conception of the son than at the conception of the father.

The relation of the determiners of the fertilized egg to the traits of the adult man has to be clearly seen for clear thinking. The trait as we know it in a man is merely a morphological or functional entity that has received a popular name, like blue eye, black skin, cataract, or epilepsy. These terms are merely names for end products and tell nothing about the number of chemical reactions involved in their production. As a matter of fact, blue eye, as distinguished from brown eye, is due to the absence of the determiner that makes brown iris pigment, for

every one has blue eyes at some time, but in many persons the blue is covered over by brown pigment either before or after birth. The black skin of the negro is due to *two* determiners of skin pigment, one working to reinforce the other; presenile cataract seems to be due to one extra determiner, something that causes the lens to grow opaque; epilepsy to the absence of some determiner that secures appropriate control and protection of the centers of forced movements. Even (one might say, especially) the absence of inhibitions—that permits childish and immoral behavior—probably results from a real determiner. The only way by which one can tell whether a given trait is dependent on several determiners, one determiner only, or no determiner at all is by studying the behavior of the trait in the crossing of strains or biotypes—*i.e.* crossing strains having the trait with strains that lack it.

As we have seen, it is not the trait that is inherited but only a determiner for the trait. But the determiner is a differential only and does not insure the full development of the trait, any more than a seed insures a good yield. In order that the determiner shall fully develop its potentialities it is necessary that good conditions for development should be present. The determiner for educability may be present but its full potentialities are yielded only when suitable means of education are provided. Similarly, resistance to tuberculosis may be present in the body but it may have a poor chance to develop, owing to bad conditions of life.

When the point of view of the preceding paragraph is fully grasped the difficulty that some people find in understanding how a disease that is "due" to a germ can be "hereditary" disappears. For what is inherited is the chemical constitution–or rather the determiners of such—and upon that chemical constitution depends the ability of the parasite of a given constant virulence to grow luxuriantly, poorly, or not to grow at all. The hereditary constitution is not a constant thing, even in a pure-bred strain. It varies between individuals, depending upon the degree to which the conditions of development have favored it. It varies in the same individual from time to time according to the "condition" of the individual–as one says of a person: "he was underfed, and starved for air and his resistance was broken down."

To repeat, then, we do not inherit characters, traits, but only the determiners or differentials for them. We do not inherit, strictly, from our parents but we resemble our parents for the same reason that we resemble our uncles or first cousins, because we and they have common determiners derived from a common germ-plasm. This germ-plasm is the totality of the germ cells, or strictly just that portion of the germ cells that seems, paticularly, to carry the determiners (known as the chromosomes). Finally, there is a determiner for each *unit* character but the unit character is not the same as the trait as we know it; on the contrary, a trait as we know it may consist of more than one unit character, or of one only, or it may be due to the absence of a unit character that is commonly present—as blue eye is due to the absence of the unit character: brown iris pigment. Thus traits are referable to unit characters, each of which depends upon a determiner in the germ-plasm, and this determiner is the real inheritable unit.

One other principle, of great importance, remains to be considered. If all germ cells on both the paternal and maternal sides of the house contain a determiner for a given unit character, then in the zygote resulting from the union of egg and sperm, there are two determiners—the determiner is said, in that case, to be duplex. In the unripe germ cells of the individual that develops from this zygote the determiners are still duplex; but in the last cell division—the maturation division—the elements of the pairs are separated from one another and in each and every ripe germ cell the determiner for the character is simplex again. But it frequently happens that the two parental germ plasms are different, in that one possesses, while the other lacks, the determiner for a character. Then in the zygote this determiner is simplex in each cell and in the unripe germ cells of the adult. In the maturation division of these germ cells, the simplex determiner goes, in each division, to one of the two daughter cells and the other is left without any determiner. That is, half of the ripe germ cells are simplex in respect to the determiner and half are without any determiner at all or are nulliplex. The progeny of two parents of this type, whose germ cells are half of one kind and half of another, will be of three kinds because there are three kinds of unions of the germ cells—three kinds of zygotes; zygotes resulting from the union of two germ cells each with a determiner; zygotes resulting from the union of germ cells of which one only has the determiner; zygotes resulting from the union of germ cells neither of which has the determiner; *i.e.* duplex zygotes, simplex zygotes, and nulliplex zygotes and these appear in the ratio of 1:2:1. Since the duplex and simplex zygotes are often indistinguishable, there may be three individuals of one kind and one of the other. This is the 3 to 1 ratio of which we heard so much in the early studies on "Mendelism."

The foregoing principles may now be illustrated by an example, namely, eye color. The iris consists of a mesh of connective tissue in the rear of which particles bearing a purple-blue color are located. These give the typical blue color of the iris. Yellowish pigment, doubtless allied to that seen in red hair, is also present in greater or less amount and, backed by blue, gives the *green* iris color. In many eyes (taking the world over, in the vast majority of them) brown pigment is laid down in the iris. The amount of brown varies in area and in intensity from dark brown to a light brown and to a condition of brown spots, usually massed around the pupil but sometimes scattered irregularly over the surface of the iris. For the sake of simplicity we will here consider only the brown pigment and the blue iris. Now (1) if both parents belong to pure strains of brown-eyed people all germ cells will carry the determiner for brown pigment and all the children will have duplex brown eyes. (2) If one parent belongs to pure brown-eyed stock, while the other is a simplex brown all children will have brown eyes, but in half the color is simplex. (3) If both parents be simplex one-quarter of the offspring will be blue-eyed. (4) If one parent be duplex brown-eyed and the other blue-eyed all of the children will be simplex brown-eyed. (5) If one parent be simplex and the other blue-eyed, half of the children will have blue eyes. (6) If both parents lack brown pigment in the eyes all of the children will also lack it. These six cases are illustrative of the six cases that matings of a simple unit character usually fall into.

But not all human traits are inherited in so simple a fashion as eye-color. Some apparently simple characters are really compound, as shown by the way they are inherited. Thus, the pigmentation of the negro skin is due to *two* (paired) determiners each of which does the same work as the other. In the mulatto only one of these determiners (composed of two factors) is at work, consequently the pigmentation is half as dark as in the negro. In the quadroon there is only one factor at work; and in the sambo three factors. The octoroon apparently has no factor at all for brown skin color.

All simple traits (dependent on a single determiner) fall (so far as we know) into three classes: (*a*) those due to the presence of a determiner, (*b*) those due to the absence of a determiner, (*c*) those that are sex-linked. Really these are not three methods of in-

heritance, but one only. For corresponding with every trait that is due to a determiner is a trait that is due to its *absence*. And the sex-linked traits are, according to the current theory, those that are due to the absence of a determiner from the "sex chromosome"; *i.e.* the chromosome that determines many other character of sex, especially the character of the sex cells. This sex chromosome is peculiar in that it is always simplex in the male and hence all "sex-linked" characters are simplex.

With this explanation a list of traits of the three classes (so far as determined) may now be given.

a. One of the clearest of *positive* traits is Huntington's chorea, a condition that ordinarily develops rather late in life. If the determiner of the tendency is in the germ plasm of the zygote—the child—it will, if he lives long enough, develop in his soma as a chorea. If it is in the soma of a parent, at least half of the germ cells of the parent will have the determiner for it and some of the children will have it. But a parent, without the trait, though of choreic stock, will, typically have no affected children. The fact that the stock to which this person belongs contains this inheritable and highly undesirable trait is no reason for denying marriage to such a normal person.* Other examples of positive traits are presenile cataract, displaced lens, glaucoma, retinitis pigmentosa (probably), night blindness, epidermolysis bullosa, tylosis of palms and soles, monilithrix (or beaded hair), telangiectasis, chronic family jaundice, hypospadias, cryptorchism, polydactylism, syndactylism, brachydactylism, double-jointedness of the fingers, and crossed toes. To this list may probably be added certain elements of hysteria, such as liability to violent outbreaks of temper (tantrums) and strong eroticism (nymphomania). In general, the normal (*i.e.* unaffected) descendants of such stock may not be denied marriage; but affected persons will have at least half of their children similarly affected; and, if the disease is an important one, they should not have children.

On the other hand, many conditions are due to a defect. A normal person may carry the defect in some of his germ cells but it will appear in his progeny only if one of these defective germ cells unites with a similarly defective germ cell from the other parent. It makes no difference whether the trait has appeared in representatives of the past few generations of ancestors or not. The great difficulty in advising in this class of cases is due to the fact that, since the germinal defect is hidden, its reappearance in later generations is less easily guarded against. Where such a hidden possibility is feared, the first caution is to avoid cousin marriage. The second caution is to avoid marrying into a strain with the same defect, even though the proposed consort does not show the defect. If a study of the family history of the partners shows the same defect it is desirable that the engagement to marry be broken. Examples of such traits are albinism, excessive growth in stature (probable), imbecility or marked general mental defect, hereditary epilepsy, myoclonic epilepsy, dementia precox, manic-depressive insanity (in some cases or some of its elements, at least), extreme alcoholism and dipsomania (probable), cerebral palsy of infancy, hereditary ataxy, Thomsen's disease, congenital deafness (but this is complex and probably many factors are involved), otosclerosis (probable), non-resistance to cancer, to tuberculosis, and to catarrh-inciting causes. Many of the commonest diseases and defects belong to this category. The possession of these conditions is often considered a bar to marriage and yet the case is with them very different from [illegible]. For the latter [illegible] the children of an affected parent while the former may not and, in appropriate matings, *cannot* reappear in the bodies of the offspring of such affected parents. To be sure, the germinal defects are continued; but if care is taken in the mating [illegible] the defect may be kept from appearing [illegible]. No doubt it were better for [illegible] insane, and consumptives not to marry; but if there are strong reasons why a person affected with [illegible] these conditions should marry, then, for the sake of the children, let the mating be made with persons or into strains that are not defective in the same way.

Finally, there is the third set of cases, the sex-limited. These appear, typically, in one sex only, the male, and are transmitted in a peculiar fashion as the "knight's move" form of heredity. That is to say, affected fathers have ordinarily no affected children but the defect lies in the germ cells of the daughters and when they, in turn, become mothers it reappears in half of their sons. The reason is that, in the case of these sex-limited traits, the sons inherit from the germ plasm of the mothers only, but the daughters inherit from both parents and, consequently, if one parent is normal the daughters, also, will be normal, though capable of transmitting the defect to their sons. The following conditions appear to be inherited in a sex-limited fashion, color blindness, atrophy of the optic nerve, multiple sclerosis, ichthyosis, muscular atrophy, and hemophilia. Advice on this class of cases is this: affected men should not marry if the defect is decidedly undesirable, since their daughters, though somatically normal, will carry the defect in half of their germ cells. Women who have an affected father or an affected brother should not marry; but normal sons may marry into outside strains with entire impunity. They carry no taint of the defect even in their germ cells.

Consanguineous Marriage.—One of the [illegible] inquiries made of the physician is as to the propriety of the marriage of two young persons who are cousins or nearer relatives. There has been much legislation on this matter in the different States of the Union. All States (except Tennessee, probably due to an oversight) forbid the marriage of brothers and sisters "of the half or the whole blood." All forbid the marriage of child and parent. Twenty-two out of forty-eight forbid the marriage of first cousins. It is significant that the States that do not forbid cousin marriage include most of the older states, and this is doubtless because cousin marriages were very common in Colonial times. Thus cousin marriages are legal in Maine, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Delaware, Maryland, Virginia, West Virginia, South Carolina. Pennsylvania is the most striking omission from this list, among the thirteen original states. What answer can be given first cousins who wish to marry each other and who inquire about the danger to the children? First, it cannot be maintained that cousin marriages always produce defective children. Charles Darwin married his first cousin and all of his five sons have been men of exceptional ability and good vitality. Roger Wolcott, governor of Connecticut, married his first cousin, Sarah Drake. Their children included Roger Wolcott, Jr., a judge of the Superior Court; Oliver Wolcott, a signer of the Declaration of Independence and governor of Connecticut; Erastus Wolcott, a justice of the Supreme Court of Connecticut and a speaker of the Connecticut House; and Ursula, who married her second cousin once removed, Matthew Griswold, a governor of Connecticut, and had a son, Roger Griswold, also governor of Connecticut. Again, Fidelia Dwight and Jonathan Edwards Porter, both grandchildren of Jonathan Edwards of the Connecticut Valley, married each

*It is to be noted that in this particular case it is difficult or impossible to tell at the usual age of marriage whether a young person, one of whose parents was choreic, will eventually develop the disease or not. It is better, in each case, to delay marriage until the age of onset of the disease in the affected parent.

other. They had five children: Julia, of brilliant intellect; Timothy, proprietor and principal of Washington Institute and other schools, a man of literary tastes and capacity: Theodore, a teacher all his life; and two sons who died at birth. These instances might be multiplied. On the other hand it would be easy to cite many cases where the children of first cousins are mentally or physically defective. The reason why cousin marriages sometimes produce defective progeny and sometimes progeny of the highest order of intelligence is very simple. Cousin marriage permits two persons with the same defect in the germ cells to become the progenitors of offspring that get the normal condition from neither side of the house and hence must show the family defect. On the other hand cousin marriage may bring together a double dose of the special ability that characterizes a family. There is danger in cousin marriage whenever (as is so frequently the case), there is a marked family defect; but, on the other hand, in the absence of a marked family defect cousin marriage may perpetuate and even strengthen a desirable quality.

Eugenic Marriages.—These should be strictly distinguished from hygienic marriages with which they are often confounded. Personally, I anticipate that the provisions for a physician's certificate before marriage will, in the long run, tend to increase the marriage density by removing the fear of infection which the modern sex hygiene propaganda has made so vivid to many a young woman, that she shuns marriage—such testimony I have received, at any rate, from young women. Eugenic marriages, on the other hand, seek to secure physical and mental health to the children by the proper matings of good stock. All of our States have laws limiting the right of marriage of the mentally defective or afflicted, but these laws do not square with modern knowledge and they are actually inadequately enforced. I have elsewhere (Eugenics Record Office, *Bulletin* No. 9), urged that each State should organize a State Eugenic Board which should comprise a trained biologist, a general practising physician of experience, and a general practitioner of law of broad experience to devote its entire time to its duties. It should appoint the State official physicians and the field workers, and direct the administrative office and records of the Board. To it should be referred for decision, all questions of the granting of licenses in cases where special consideration is clearly required. The vast majority of marriages in any State will not be considered by a board. If ten per cent. were, that would mean for New York State about 10,000, or thirty a working day; for Ohio, about 5,000; for Kansas and Virginia, about 1,700 per year each.

The plan calls also for the appointment of Official Physicians of the State. These should be designated by the Eugenics Board from among the general practising physicians of each community. Since only about sixteen persons (eight pairs) are married each year per thousand of the population, and since a physician could consider on the average, say, two a week without greatly interfering with his other engagements, one official physician could certainly take care of a population of 10,000 and in large cities, the proportion could be increased to one in 25,000 or even 50,000 of the population. In a state like New York, with 9,113,000 inhabitants, about 500 official physicians would be required, those in the largest cities giving their whole time to the work of the Eugenics Board. The official physician should receive applications for licenses to marry; he should direct field workers to report on the family histories of the applicants with respect to the points covered by the law; he should, where the law requires a certificate of health, examine and certify such of the applicants as are of the same sex as the official physician, and secure a report upon the physical condition of the other applicant from a physician of the same sex as said applicant. If the findings of the field workers and those of the physical examination are both favorable, the license shall be furnished forthwith. If either or both the family history and the physical examination are such that there may be reasonable doubt as to the quality of the offspring, the case, with findings, must be laid before the Eugenics Board. If it is clear that the license cannot be granted legally, the application is denied forthwith and the applicants are fully instructed as to the reasons why the license cannot be granted, particularly the danger to progeny if the marriage were consummated. A written statement of the reasons for refusing the license is to be sent to the parent or guardian of each of the applicants. Appeal may be made to the Eugenics Board. In case the application is referred to the Eugenics Board and the reply from the Board is favorable, the license is granted forthwith; but in case it is unfavorable, the applicants and their guardians shall be instructed as above.

The Field Workers, referred to above, are students of family history. These shall be appointed by the Board. They shall, where necessary, and under the orders of the official physician to whom they are assigned, visit the homes of the two applicants for each license, and inquire into and report upon the existence in the family of the undesirable mental and physical conditions which the law seeks to eliminate from the race; they shall build up an index to the occurrence in the population of those traits of which the law takes cognizance, in order that, the facts being ascertained, the families concerned may be saved needless inconvenience. Duplicates of such index should be sent to the office of the State Board of Eugenics, and a third set may be deposited with a national and international depository of eugenical data, like the Eugenics Record Office.

The work of the State Eugenics Bureau and its officers may be illustrated by an example. A young man and a young woman present themselves (with an application for a marriage license) to a State physician. If the law requires a medical certificate, he examines the young man and requires from the young woman a report of examination by a reputable woman physician. He examines his files for data concerning the family histories of the applicants, so far as they bear on the traits of which the law takes cognizance. If he finds insufficient data he calls for a report from the field worker within three days. If personal and family histories are satisfactory, he issues the license forthwith to the applicants. If, on the contrary, the young man be found to be suffering from gonorrhea, the application is forthwith denied. If the field worker reports that the father of the young man and the mother of the young woman were brother and sister, and both were victims of manic-depressive insanity in a bad form, the application is likewise denied, with a full explanation of the reasons therefore. But if the young man have an epileptic brother or sister and no neurosis appear in the young woman, who is a second cousin of the young man, and if the family history is otherwise such that the physician is doubtful as to the the decision he should render, the matter is referred by him to the State Board, who, after examining all the papers in the case and by the use of its own index to families of the State, renders a decision with the least possible delay.

For those persons who, despite a denial of marriage by the State, cohabit and have a child, the penalty should be sterilization of the male. And the father should be obliged to support the mother and child during their periods of dependency. An official physician, who has not exercised reasonable judgment in issuing licenses, is to be deprived of his office and rendered unable thereafter to hold public office.

With the Eugenics Board should be left the execution of all laws limiting procreation, both inside the

marital relation and outside. It is probable that the expenses of the Board, physicians, and field workers could be met by the license fee of an amount that would not be prohibitive. Thus a fee of ten dollars would bring an income of $1,000,000 to the State of New York, and this would probably meet a large share of the expenses of the undertaking.

Immigration.—While efforts are being made to secure the reproduction of sound children we must not forget that hardly less than one-third of the additions to our population in any year is by immigration; two-thirds only by reproduction. Moreover, since the recent immigrants are more fecund than the older stock, it is probable that half of the increment to our population each year is from immigrants and the progeny of persons who were married before they came to this country, and, hence, have been outside the jurisdiction of our laws in their mating. It is clear that the purpose of the State Eugenic laws cannot be fulfilled unless some adequate selection be made of immigrants.

Selection, as it is at present exercised at a port of entry, is entirely inadequate, since from the eugenic standpoint we want to know about qualities of the germ-plasm rather than merely qualities of the soma, which is all the inspection at the port considers. We want to know more about our immigrants than that they will make good "hands." We want to be assured that they will beget sound progeny. And the only way to judge of this point is to investigate their family history, abroad. We admit a Czolgosz, a Schrank, and a Schmidt or their parents and the whole nation suffers from their crimes and *then* we look into their family history abroad and find it so bad that, illogically enough, we may not cut them off, but continue to protect and feed them for the rest of their lives. At little more than the cost of the head-tax now collected from immigrants we could have in hand his family history before the immigrant is allowed to land, determined by investigations made while the immigrant was on the sea, the results being cabled over.

Physicians as Eugenicists.—Physicians because of their intimate relations with families are frequently consulted on matters of marriage. It is then clear that it is their privilege and duty to inform themselves of the progress of studies in heredity and eugenics; and to keep in touch with those who are making special studies on these subjects so that they can direct their families to them for special advice. The day is coming when the duty of the profession of medicine will be conceived more largely than that of curing the sick. The sanitary official enforces the laws of public hygiene, but the physician has as his special care race hygiene. The physician, by good advice as to marriage matings, may help to keep down the reproduction of defectives. By urging those of our best stock who are well mated to have large families so that the good qualities of that stock may be passed on to the next generation, he will help as effectively as a general to preserve the nation.

Segregation and Sterilization.—The eugenic treatment of mentally defective or mentally diseased persons and of those who are morally uncontrolled is coming to be more and more a matter of State concern. Useful as it is to confine such persons for a period it is much more important to segregate them throughout the reproductive period. Recently twelve states have placed on their statute books laws for the prevention of procreation of certain classes of persons–chiefly for eugenic reasons. These states with the date of the laws are Indiana (1907), Washington (1909), California (1909), Connecticut (1909), Nevada (1911), Iowa (1911), New Jersey (1911), New York (1912), Kansas (1913), Wisconsin (1913), Michigan (1913), North Dakota (1913). The Oregon legislature passed the law but it was defeated in referendum, by a small majority. Evidently there is a large social support for [illegible]. They appeal partly [illegible]. They may reach the desired result of [illegible] race in a more rapid and [illegible] segregation.

The Eugenics Record Office [illegible] in 1910 by Mrs. E. H. Harriman, seeks to realize the ideal of a clearing house for [illegible] data. Here, at Cold Spring Harbor, Long Island, New York, data are being [illegible], and the results of the studies published. Upon presentation of full data answers are given [illegible] as possible, to inquiries about [illegible]. The Eugenics Record Office cooperates with [illegible] intendents of State institutions who wish to secure family histories of patients. It trains eugenic field workers and annually supplies a limited number of them to State Institutions paying salaries, but not expenses. It requires data for its investigations and it seeks the cooperation of physicians in furnishing them, with the assurance that they will be held in strictest confidence and used merely for [illegible] statistical study. Thus it subserves both a scientific and a social function. The scientific work of the Eugenics Record Office is directed by a Board composed of: Alexander Graham Bell, chairman, William H. Welch, vice chairman, Lewellys F. Barker, Irving Fisher, E. E. Southard, Charles B. Davenport, secretary and resident director. Its superintendent is H. H. Laughlin. It has already (February, 1914) published 12 Bulletins, 2 Memoirs, and a Report.

CHARLES B. DAVENPORT.

Eugenol.—See *Caryophyllus*

Eugenol-acetamide. ($C_6H_3.C_3H_5.OCH_3.OCH_2.CONH_2$) is obtained by the action of monochloracetic acid on eugenol sodium, with subsequent heating in the presence of ammonia. Its chief or only employment has been as a local anesthetic in dentistry.

R. J. E. SCOTT.

Eugenol Iodide.—Iodo-eugenol ($C_6H_2I.C_3H_5.OCH_3.OH$). This a is yellowish powder, insoluble in water, and odorless, obtained by the action of iodine on eugenol sodium. It is used as a substitute for iodoform.

R. J. E. SCOTT.

Euglenoidea.—An order of flagellate protozoans, which are usually non-parasitic and often contain chloroplasts. See *Protozoa*.

A. S. P.

Eugregarina.—A suborder of the *Telosporida*, in the Sporozoa. Reproduction is usually by sporogeny; schizony is very rare. See *Protozoa*.

A. S. P.

Eunatrol is a proprietary preparation said to consist of seventy per cent. of sodium oleate and thirty per cent. of oleic acid. Cholagogue properties are claimed for it. Dose, one gram (gr. xv.) three times a day.

R. J. E. SCOTT.

Euonymus.—WAHOO. Spindle tree, Burning bush, etc. The dried bark of the root of *Euonymus atropurpureus* Jacq. (fam. *Celastraceae*).

This plant is a graceful shrub or small tree of the Eastern and Central States, and is frequently cultivated for its beauty. It is usually about eight to twelve feet high, with opposite, oval-oblong, pointed, serrate leaves, and small regular, dark purple flowers in axillary cymes. Sepals, petals, and stamens usually four; the latter inserted on a disc which extends over the ovary; pistil one; ovary three- to five-lobed and three- to five-celled, with several ovules in each

cell; pods deeply lobed, smooth, bright crimson, drooping on long slender peduncles.

The bark occurs in quilled strips or pieces of very irregular size, usually with a few fine hair-like roots adhering; bark one to five millimeters (one-twenty-fifth to one-fifth inch) thick; outer surface ashy or pale brownish-gray, usually with some small dark patches, shallowly fissured and ridged, with a somewhat scaly and soft, friable cork; inner surface whitish or slightly tawny, indistinctly short striate; fracture short, whitish, or the inner layer pale brownish in bark which has been long kept; when it is slowly broken, the fractured ends are held together by fine, somewhat elastic fibers; odor distinct and characteristic, more or less saponaceous; somewhat gummy in the mouth, the taste sweetish, bitter, slightly acrid.

The stem bark, which is in long, tough strips, with a dark gray or blackish cork, should be rejected.

The constituents of wahoo are not very well made out. Several resins, oil, wax, and numerous more ordinary substances have been obtained from it, as well as a glucoside named *euonymin;* indeed, several "euonymins," of somewhat different characters, have been separated by as many chemists. From all of these, again, is to be distinguished the resinoid "euonymin" obtained by precipitating the tincture. Of the latter there are two forms: the "brown," made from the official bark, and the green, made from the stem bark, the latter being inferior.

Uses.—Wahoo is a not very certain, usually gentle, but sometimes griping laxative, with a reputation as a cholagogue. It may be given in chronic constipation, or perhaps better in occasional attacks of constipation with dyspepsia, heaviness, and symptoms of diminished hepatic action.

Dose of the extract (*Extractum Euonymi*, U. S. P.), gr. i.–iij. (0.06–0.12) in pill form once or twice a day.

Henry H. Rusby.

Eupatorium.—Thoroughwort. Boneset. The dried leaves and flowering tops of *Eupatorium perfoliatum* L. (fam. *Compositæ*). This is a widely distributed species, growing in the greatest abundance about the borders of ponds and brooks, and in wet places generally, from Canada to Florida, and from the eastern to the western side of this country. It is a handsome, large, perennial herb, with a hairy, rather simple stem, growing from two to four or more feet high, large, dark green and completely connate pairs of rough hairy leaves, and flattened, complex, cymose clusters of small heads of minute creamy-white flowers.

Description of Drug.—Leaves opposite, the two united by their broad bases, the uppermost often distinct, those of the inflorescence mostly alternate and greatly reduced; eight to fifteen centimeters (three to six inches) long and one and one-half to five centimeters (three-fourth to two inches) broad, tapering regularly from near the base to an acute apex, crenate-serrate, above bright green or somewhat yellowish-green, rugose and finely bullate: underneath yellowish-gray-green, densely short hairy and resinous dotted, the prominent, rounded, crooked, fine veins conspicuously reticulated; flower-heads very numerous, in broad corymbs, the branches rough hairy; mature involucre campanulate, the imbricated scales lanceoblong, obtusish, green, hairy, the inner longer and with whitish tips and margins; flowers of the head about ten to sixteen, tubular, yellowish-white, the pappus in a single row, white, bristly; odor weak, aromatic; taste bitter, astringent, aromatic.

The constituents of thoroughwort are chiefly the bitter glucoside eupatorin, which is soluble both in alcohol and in boiling water, a very small amount of volatile oil, a glucosidal tannin, which constitutes the coloring matter, and another tannin. There are also gum, resin, and ordinary plant constituents. The presence of an alkaloid has been reported, but this subject requires further investigation.

Use.—Boneset has been long used in the United States as a tonic and antiperiodic, and even as an emetic, but always more of a family medicine than one prescribed by physicians. In small doses thoroughwort is a mild bitter tonic, like the chamomiles and others in the same family, but with less aromatic character than most of them. It is also a good deal like horehound in the *Labiatæ*. In larger doses, especially in hot infusion, it is diaphoretic, possibly diuretic, and is still occasionally used, followed by a sweat under blankets, to abort colds, and in the beginning of most acute diseases. In very large doses (an infusion of an ounce or so) it is a nauseating emetic. Doses as large as can be borne by the stomach, repeated for some days, formerly had a considerable reputation in the country in the treatment of intermittent fever and other malarial manifestations.

In domestic practice thoroughwort is usually given in the form of a decoction, especially when its diaphoretic, antirheumatic, or antiperiodic action is desired. Physicians also often prescribe it in that way, though more often at the present time in the form of the fluid extract. The dose of the latter, of which 1 c.c. is the equivalent of one gram of the drug, is ♏ x. to xv. (0.6–1.0) as a tonic, ♏ xv. to ʒi. (1.0–4.0) as a diaphoretic and antiperiodic, and two or three times as much as an emetic.

Allied Species.—The genus *Eupatorium* comprises many hundreds of species, a large number of which, in various countries, are employed similarly to the above. Numerous plants belonging to related genera have similar properties. (See *Compositæ*.)

Henry H. Rusby.

Euphorbiaceæ.—(*The Spurge Family.*) One of the most important medicinal families of plants, if we consider its domestic as well as its professional uses. It contains more than 200 genera and 3,000 species, distributed over almost the entire earth, most abundant in the tropics, gradually decreasing with the temperature, and wanting in very cold regions. Their most notable property is their great power of adaptation to environment, so that some of them thrive equally well in the most arid deserts, and amid luxuriant floras. Their economic value is great in other than medicinal directions. Two of our best rubbers are yielded respectively by the manihot and the heveas. Other manihots yield the highly important food cassava and its starch, tapioca. Some of the fruits are edible, and some of the timbers have special uses. Numerous species yield useful fixed oils, and several dye-stuffs are obtained. Medicinally, the properties depend almost entirely upon local stimulation or irritation, even the "alterative" effects probably depending ultimately upon some such depurative action. This irritating action increases in many species to the point of rendering them violent poisons, either externally or internally, or both. These irritating principles exist commonly in the milky juices with which the tissues abound, these being frequently highly caustic to the skin or other tissues. Even such violently acting juices have often been utilized as escharotics or epispastics. Among such juices we may mention those of *Hura*, *Euphorbia heterodoxa* Muell (Alvelos), and other species of this genus, *Hippomane*, *Toxicodendron*, *Ophthalmablapton*, and *Excœcaria*. The latter acts violently even by access of its smoke, and smoking the body with it is, among the Fiji, a heroic treatment for leprosy. Juices, mostly milder in their action, are used internally as irritant purges, but many of them in overdoses may prove emetico-cathartic poisons. Rarely do these purgatives consist of the extracted juice, as in

euphorbium, but usually of the tissues containing the latex, fresh or dried, or medicinal preparations of them. Among such may be mentioned the root of *Jatropha macrorhiza* Benth., of *Stillingia*, of *Euphorbia Ipecacuanhæ* L., *E. Lathyris* L., *E. marginata* Pursh., *E. corollata* L., *E. Cyparissias* L., and other species of this genus, the spurges, the herbage of *Mercurialis*, *Tragia* sps., and *Joannesia*, and various parts of many species of *Croton* and *Phyllanthus*. Many of the latter are also used as fish poisons. In other cases, the purgative constituent is, or resides in, a fixed oil, usually of the seeds, as in croton, castor, and curcas oils. Powerful albuminous poisons usually also reside in these seeds. A number of special or exceptional drugs, like kamala and cascarilla, will be found discussed in their proper alphabetical order. A complete enumeration of the medicinal species of the family would fill several of these pages.

HENRY H. RUSBY.

Euphorbium.—An irritating and drastic gum resin, obtained from *Euphorbia resinifera* Berg (fam. *Euphorbiaceæ*). This is a large, leafless, cactus-like perennial, growing from four to six feet high, having a thick, gray, woody stem, and numerous very fleshy, quadrangular, spiny green branches. The plant is laden with a milky juice, which exudes when it is wounded, and dries readily in tears upon the surface or entangled among the spines. It is a native of the interior of Morocco.

The resin is reported from Mogador. It has been known in European commerce from a very remote period, is mentioned by numerous older medical writers, and had its place in most pharmacopœias, but its use is now nearly obsolete, except in veterinary practice. It is collected by incising the stems early in the season, and collecting the hardened tears some weeks later. These are usually irregular, from the size of a hickory nut down, yellow, translucent, with a dull, waxy surface, and a brittle fracture. They often enclose or fasten spines or other portions of the plant. Frequently they are perforated. The odor is slight, unless heated, but the dust raised by gathering, sorting, or powdering it is exceedingly irritating to face and nose, so that those handling it should wear veils, or take means to avoid the dust. Flückiger's analysis of euphorbium gives it the following composition: *amorphous resin*, 38; *euphorbon*, 22; *mucilage*, 18; *malates*, 12; *inorganic ingredients*, 10. Of these, the irritating and active principle is the amorphous resin. It is soluble in alcohol.

ACTION AND USE.—Euphorbium is a violent irritant, like cashew nuts, chrysarobin, croton oil, etc.; it is also, like the latter, an irritant drastic. Formerly it was used internally for this quality, but is now never so given. For external use as an irritant, or, more generally, diluted with other things, as a rubefacient (ointments, plasters, etc.), it is occasionally called for, and in the more obstinate chronic skin affections has some value; but the necessity which cannot better be met with other medicines must be rare.

W. P. BOLLES.

Euphthalmin is the hydrochloride of the mandelic acid derivative of beta-eucaine. It is soluble in water and in alcohol, can readily be sterilized, and has been employed as a mydriatic, in five per cent. solutions.

R. J. E. SCOTT.

Eupopoidea.—One of the subdivisions of the ticks of the suborder *Prostigmata*. The prostigmata have simple palpi in which the last joint is not bent downward. The body may possess a few hairs. The genera *Tydeus* and *Pediculoides* are parasitic on man. See *Arachnida*.

A. S. P.

Euproctis.—A genus of [illegible] is the brown tail moth of [illegible] The hairs on the caterpillar [illegible] trouble. See *Insect*, [illegible]

Eupyrin is a compound of [illegible] ethyl carbonate. It is soluble in alcohol or ether but not in water, and has [illegible] pyretic but is of no use as an antipyretic.

R. J. E. SCOTT.

Euquinine is the ethyl carbonate of quinine, and is prepared by the action of quinine on ethyl chloroformate. It is soluble in alcohol or ether but not in water. Like quinine, it gives the thalleioquin reaction; but unlike quinine, it does not give the Herapath reaction. It is almost tasteless and is also free from a bitter after-taste. It contains about eighty per cent. of quinine, and is said not to be decomposed in the stomach, or to cause headache or tinnitus. It is used as an antipyretic, also in malaria and whooping-cough; and it may be considered as a substitute for quinine sulphate. Dose, one to ten grains (0.06 to 0.6) in cachet or capsule.

R. J. E. SCOTT.

Eureka Springs.—Carroll County, Arkansas.

POST OFFICE.—Eureka Springs. Hotels: Crescent, Basin Park, Allred, Palace, and numerous other houses.

ACCESS.—Via Missouri and North Arkansas Railroad from the south and southeast. From points about and to the north and west of Kansas City, the choice of two routes is offered to the traveler; one over the Frisco via Monett and Seligman, Missouri; the other over the Kansas City Southern via Neosho.

Where a few years ago was an uninhabited sterile mountain glen, on the summit of the Ozarks, now nestles a bright little city of some 5,000 inhabitants, which number is greatly increased by the large floating population of visitors, tourists, business men, and invalids constantly coming and going. The city is lighted by electricity, contains an electric railway system, and excellent schools, and hotels. The Interstate Summer Normal and Educational Assembly have erected a building with a seating capacity of five thousand persons, in which annual summer sessions are held and attended by visitors from all parts of the Union. Crescent College and Conservatory is also located here. Within the corporate City limits are fifty springs, the best known being as follows: The "Crescent," "Dairy," "Basin," "Magnetic," "Harding," "Little Eureka," "Sweet," "Grotto," "Mystic," "Oil," "Arsenic," "Cave," and "Cold" springs. The waters contain mainly carbonates of calcium and magnesium, with [illegible] proportion of sulphates and chlorides. They are not strongly mineralized, and differ but slightly from each other.

The following is the analysis of Basin Spring water:

ONE UNITED STATES GALLON CONTAINS

Solids.	
Sodium chloride	[illegible]
Sodium sulphate	[illegible]
Sodium bicarbonate	[illegible]
Potassium sulphate	[illegible]
Calcium bicarbonate	[illegible]
Magnesium bicarbonate	[illegible]
Iron and alumina	0.08
Silica	[illegible]
Total	[illegible]
Albuminoid [illegible]	[illegible]
Free ammonia	[illegible]

It has been estimated that there is in each gallon of Eureka Springs water 28.52 cubic inches of gaseous contents. The fact that there is a large proportion of nitrogen present makes the gaseous contents remarkable. A large proportion of nitrogen means a proportionately large amount of oxygen.

The waters of Eureka Springs are radioactive—some to a marked degree.

RADIOACTIVITY OF THREE SPRINGS TESTED.

Uranium grams x 10^{-12} as the standard

Basin spring, cold	6.5	Miller, observer
Sweet spring, cold	4.2	Miller, observer
Magnetic spring, cold	0.013.	Miller, observer.

Since the water loses its radioactivity soon after it is taken from the spring, it should be used when fresh.

The following table, shows some of the climatic advantages of the resort:

Eureka Springs.

Altitude above sea level		2,000 ft.
Annual average; precipitation		32.79 in.
Mean temperature (Fahr.	Spring	60.85°
	Summer	74.79°
	Autumn	48.01°
	Winter	42.08°
Annual average		56.43°
Relative humidity (per cent.)		58.93
Average number of days per annum	Clear weather	209
	Fair weather	90
	Cloudy weather	66

The city is picturesquely located at the headwaters of the White River in the Ozark Mountains. A sojourn at Eureka Springs and the free use of its waters are stated to be beneficial in a wide range of affections, including rheumatism, gout, gastric catarrh, dyspepsia, skin, nervous, renal, liver, and bladder disorders, diseases of women, hay fever, general debility, and even some forms of paralysis.

EMMA E. WALKER.

Euresol, or resorcin monoacetate, $C_6H_3(OH)_2.CH_3CO$, is a yellow, oily liquid, soluble in acetone. It has been used in various skin diseases as a substitute for resorcin; and is employed either as an ointment, or (in acetone-solution) as a varnish.

R. J. E. SCOTT.

Eurhipicephalus.—A genus of ticks in which there are distinct eyes. The base of the capitulum is broader than long and is hexagonal or the dorsal surface forms a projecting angle on each side; palpi short and broad; first coxa with two large teeth. *E. appendiculatus* spreads *Babesia parva* among cattle, causing "coast fever" in Africa. *E. bursa* is widespread in Southern Europe on sheep, horse, dogs, and cattle; *E. sanguineus* is common and spreads diseases among dogs; other species are of less importance. See *Arachnida*.

A. S. P.

Eurobin, or chrysarobin triacetate, is used in various skin diseases in the same way that chrysarobin is.

R. J. E. SCOTT.

Europhen.—This is one of the many compounds containing iodine and devoid of any disagreeable odor, that have been introduced as substitutes for iodoform. Its relation to cresol and iodine is much the same as that of aristol to thymol and iodine.

It is an extremely light amorphous yellow powder, being about five times as bulky as iodoform, with an aromatic odor resembling saffron. It contains 27.6 per cent. of iodine. The use of europhen is indicated in all cases in which iodoform is employed.

BEAUMONT SMALL.

Eustachius, Bartolommeus.—Eustachio, or as the name is more commonly written Eustachius, was born in San Severino, Italy, about the year 1500. He studied medicine in Rome, and became distinguished, even at that early stage of his career, as a man of superior intelligence and great industry. He soon manifested a pronounced taste for the study of anatomy, and, shortly after he received the degree of Doctor of Medicine, the University made him Professor of Anatomy. His death occurred in August, 1574.

One of Eustachius's most important works is that entitled: "Opuscula anatomica, etc." Venice, 1564, and Leyden, 1707. In this book he gives perfectly correct descriptions of the following parts of the organ of hearing: the internal and the anterior muscles of the malleus; the stapedius muscle; the tubes which still bear his name, and the original discovery of which he attributes to Alcmæon; the cavity of the cochlea; and the stapes, the credit for discovering which he claims for himself. (Ingrassias and Colombo both made the same claim.) He also described more accurately than his predecessors had done, the vestibule of the labyrinth and the chorda tympani nerve. Another work, which unfortunately is incomplete, owing to the loss of the accompanying text, is entitled "Tabulæ anatomicæ etc." Rome, 1714, and Leyden, 1744 and 1762.

A. H. B.

Eustrongylus.—A synonym for *Dioctophyme.* This genus of round worms includes very large *Strongylidæ* with a collar-like bursa, six oral papillæ, and one spicule. The female has one ovary; ulvula in the anterior half of the body. *D. renale* usually lives in the kidney in the dog, seal, otter, and wolf. It has also been recorded from man. See *Nematoda.*

A. S. P.

Euthanasia.—According to Stedman's Dictionary, euthanasia is "a popular term for the alleged practice of putting an end to life by artificial means in cases of incurable and painful disease." Obviously few physicians are in practice self-reliant and strong-minded enough to undertake any quasi-responsibility by the performance of this action.

And yet it has undoubtedly at rare times adequate sanction in the philosophy of human personality whether we call this ethics, biology, or what not. The theoretical considerations go deeply into the principles of things and as all sapient men know such "principles" and such considerations are matters of individual temperament and even of temper, just as physiologically sometimes one man's meat surely is another man's poison, and for the same reason, that every individual is unique in every fiber, material and psychical, of his being.

The euthanastic problem clearly is somewhat one with that of suicide, and both in the ultimate analysis of relations come back to one's personal attitude toward fundamental truths, especially as to whether he be an individualist, or an utilitarian of the Mill brand and on a biologic basis. Even in the latter case there is little opposition so far as euthanasia is concerned, for it is not at all obvious how "the greatest good of the greatest number" is served by the suffering of a dying individual, even granting the remote possibility that a natural or scientific miracle might at length restore him, one in a thousand, to life.

The whole living world acts in the last analysis on the doctrine of probabilities and there is no reason why it should not dominate behavior here as universally elsewhere, and the physician only undertakes somewhat more than ordinary responsibility in estimating to his best ability the chances of recovery.

In practice these chances, it would seem, must be

near the zero in order to justify the act, and the sane desire or consent of the patient must be certain either directly or by indirect presumption so strong that it amounts to practical certainty. If a patient be unconscious, obviously the enthanastic problem does not exist, because there is no agony, and psychological observation shows how frequently bodily reactions apparently painful to the individual are in conscious experience not so at all. The problem, too, could apply seldom to children, partly because their individual wills and self-knowledge are not yet fully developed and partly because of their relatively great powers of recuperation and repair.

As a problem of pure casuistry from the patient's point of view, on the other hand, euthanasia on rare occasions seems to be on a basis of absolute equity as well as of expediency. Not only because every mortal born is forced into the conditions of life, often wearisome, troublesome, worrisome, and painful, without his consent, but purely as a matter of expediency when all other "laws" fail because in dispute, the sane adult human would seem to be chief arbiter of his mortal hours so long as (and this clearly is the case here) no other person's rights are wronged. Whether hedonist or stoic, there are limits of painful experience which no rational being mortally ill or mortally wounded would care to continue. No man in matters of life and death can afford to be too dogmatic or to cling too closely to rules of conduct based on opinion, for expediency has a pragmatic sanction of its own. It is obvious, moreover, that somewhat in proportion to an individual's assumption of and belief in the continuity of life beyond "death," the importance of a few minutes or hours or days of painful mortal life lessens into insignificance.

The usual attitude of contemporary moral philosophers on this general question of life-preservation at any cost (concerning suicide, then, and general care of one's self, as well as euthanasia) may be, I think, fairly indicated by the following paragraph from a standard text-book, Henry Sidgwick's "Methods of Ethics": "It is true that among what are commonly called 'duties to self' we find the duty of self-preservation prescribed with apparent absoluteness, at least so far as the sacrifice of one's life is not imperatively required for the preservation of the lives of others, or for the attainment of some result conceived to be very important to society. I think, however, that when confronted with the question of preserving a life which we can foresee will be both miserable and brudensome to others—*e.g.* the life of a man stricken with a fatal disease which precludes the possibility of work of any kind, during the weeks or months of agony that remain to him—though Common Sense would still deny the legitimacy of suicide, even under these conditions, it would also admit the necessity of finding reasons for the denial. This admission would imply that the universal wrongness of suicide is at any rate not self-evident. And the reasons that would be found—so far as they did not ultimately depend upon premises drawn from Revelational Theology—would, I think, turn out to be utilitarian in a broad sense of the term: it would be urged that if any exceptions to the rule prohibiting suicide were allowed, dangerous encouragement would be given to the suicidal impulse in other cases in which suicide would really be a weak and cowardly dereliction of social duty; it would also probably be urged that the toleration of suicide would facilitate secret murders. In short the independent axiom of which we are in search [a "clear, precise, self-evident first principle" as a casuistric guide] seems to disappear on close examination in this case no less than in the others." If such be the ethical conditions in regard to suicide, how very much stronger are they in regard to euthanasia from the patient's view-point! For this modified form has certainly within it the logical and rational limits of the professional sanctions of suicide, since no one is to be harmed, while the beneficiary is allowed one of the inc[illegible] sonality. The extent to which the physician's behavior will coincide with [illegible] of the patient is a matter [illegible] practitioner will decide strictly on the merits of each case in relation to his own individuality.

George L. V. [illegible]

Euthenics.—The term, Euthenics, was coined by the late Ellen H. Richards of the Massachusetts Institute of Technology, eminent sanitary chemist and pioneer in scientific home-making and in the education of women. In her book on Euthenics, The Science of Controllable Environment (Boston, 1910), she defines it as follows: "The betterment of living conditions, through conscious endeavor, for the purpose of securing efficient human beings, is what the author means by Euthenics." The word comes from the Greek εὐθηνέω (to be vigorous in body—Aristotle) or εὐθήνεια (good state of the body: prosperity, good fortune, abundance—Herodotus). It [illegible] with race improvement through environment" and is directly contrasted with eugenics which "deals with race improvement through heredity."

It is not necessary to enter here into the relative importance of the two sets of forces, eugenic and euthenic, which together control the course of human life. Both are real. With a uniform, or fairly uniform, environment, the differences between men are due to their inherited germ plasm and modern biological research more and more tends to accentuate the far-reaching effect of such hereditary differences. On the other hand with a given inheritance full realization of its possibilities depends on an environment not too unfavorable. Eugenic factors reach over and control euthenic conditions as the power of man remoulds the environment; and conversely when an epidemic or a conflagration rages future eugenic possibilities are ruthlessly cut off. It is probably true that on the whole environments do not differ among themselves nearly so much as do germ plasms, so that the net efficiency of men and of nations is governed rather by the latter than by the former. On the other hand euthenics is far easier than eugenics to control, and it is in the mastery of the environment that the greatest practical triumphs of the directive mind of man have so far been attained.

Right living conditions, which form the essential basis of euthenics, are said by Mrs. Richards to comprise "pure food and a safe water supply, a clean and disease-free atmosphere in which to live and work, proper shelter, and the adjustment of work, rest, and amusement." These desiderata may be amplified to include certain other fundamental needs and reclassified under five general headings, as follows:

1. The maintenance of proper temperature and other atmospheric conditions surrounding the body.
2. The provision of an adequate and balanced food supply.
3. The preservation of the health of the organs and tissues by exercise and their restoration when fatigued by rest and recreation.
4. Protection against injury by violence of man or beast, by accidents, fire, and the like; and
5. Protection against microbic disease.

1. The first of these five elements in a healthy environment, the maintenance of *proper atmospheric conditions* involves primarily the protection of the body against extremes of heat and cold and it is attained in its essentials by our various devices for clothing and shelter. So far as low temperature is concerned, our efforts have been successful so that in civilized communities serious suffering from cold is a rare and accidental occurrence. With the summer heat on the other hand we have dealt much less

effectively and our conquest of winter cold by the construction of more or less tight, artificially warmed, buildings has been frequently carried so far as to overstep a happy mean and produce conditions of overheating, more deadly perhaps than the unmitigated outdoor temperature.

The symptoms noted among persons exposed to the effects of "bad air" in a confined space were at first attributed to changes in the oxygen or carbon dioxide of the air or to the presence of some mysterious organic crowd poison, and ventilation was supposed to be necessary primarily for the removal of these chemical impurities. Thanks to the studies of Flügge and his successors we now know that the chemical changes in ordinary breathed air have no physiological significance and that the effects of "bad air" are due, not to its carbon dioxide or morbific matter, but, chiefly, to its temperature and humidity, and that they are exercised not upon the lungs but upon the surfaces of the skin. When the temperature passes 70°, particularly if there be much moisture present, the heat regulating mechanism of the body is hampered and ultimately overcome. Currents of wind furnish a relief by breaking up the zone of warm air immediately about the body but the real remedy is a supply of cool fresh air; and such a process of maintaining a cool atmosphere of proper humidity about the body is what we mean by ventilation. The problem of clothing is closely connected with that of air conditioning but it is clear that the regulation of air and clothing in such relation to each other as to allow adequate heat loss from the body surfaces without undue chilling or local drafts is one of the most fundamental problems in euthenics. There can be no doubt that in our overheated schools and factories efficiency is constantly lowered and health progressively undermined by the dog-day atmosphere maintained.

The control of excessive summer temperatures, too, is by no means beyond the range of practical euthenics. It is more expensive to cool air than to heat it, but the cost is by no means prohibitive. Two hotels in Chicago and one of the leading banking houses in New York are artificially cooled in summer with the most satisfactory results. The heavy incidence of diarrheal disease among infants is due to two factors, abnormal diet and the direct effect of heat, and may be prevented by breast feeding on the one hand and by protection from high temperatures on the other. Our tenement laws accomplish perhaps their most important health function when they secure at least the possibility of a circulation of air for the children in summer. There is no reason why such restrictive legislation should not be supplemented by the provision of specially cooled rooms for infants in congested districts.

Aside from the general atmospheric effects of temperature and humidity the elimination of dust and fumes comes in as a special problem in the case of factory air. Grinders and granite cutters and other operatives exposed to mineral and metallic dusts pay a toll to tuberculosis two or three times as heavy as do their brothers in healthier occupations while white lead dust, carbon monoxide, wood alcohol, and a wide variety of chemical poisons menace the workers in other industries. The organization of powerful and intelligent and cooperative bureaus of industrial hygiene to deal with these questions is one of the needs of our day, a need that at last seems to be realized in the more progressive States of the Union, as it has long been realized in England and Germany.

Housing inspection, like factory inspection, has as one of its principal motives, the maintenance of normal atmospheric conditions about the body. Fire protection, cleanliness and other factors enter in, but cool fresh air is one of the most essential desiderata in each case. The tenement like the factory must be regulated and controlled and the housing problem under the conditions of modern city planning is more difficult than the industrial one. Not restrictive legislation alone, but positive measures for substituting something better are required, which implies the erection of model tenements for reasonable rental and a constructive campaign of city planning.

2. The second essential for healthy living, following close on the need for favorable surrounding air conditions is the requirement of *an adequate supply of food.* The bodily machine requires fuel, organic matter rich in potential energy, to keep it going. It requires also certain substances, in rather definite amounts, to serve as building materials for the replacement of the tissue which is constantly broken down by the katabolic processes of the body. The energy requirement has been worked out with reasonable exactness and there is substantial agreement in the conclusion that a daily ration should supply energy equivalent to 3,000 calories for a man of average weight, engaged in moderate muscular work, to be increased for very active exercise, and to be somewhat diminished for persons of sedentary life. This energy may be obtained from any of the organic constituents of the food, protein, carbohydrate, or fat, and there is still some difference of opinion as to the best relative proportion of these classes of food stuffs. The older dietaries, based chiefly on records of actual diets, derived fifteen or sixteen per cent. of the fuel value of the food from protein while the low-protein diet of Chittenden, based on calorimeter determinations of actual physiological necessities, allows only a little more than half this proportion. The minimum level of adjustment of the body under experimental conditions seems a less safe guide than the general practice and experience of the race and it will probably be wise for normal healthy individuals to follow so far as possible the general instinct which points toward a somewhat liberal protein allowance. On the other hand the metabolism of protein puts a much greater strain on the body than does that of the non-nitrogenous food stuffs and an excess of protein in the diet promotes undesirable bacterial decompositions in the alimentary tract. For those who are troubled with digestive disturbances, or who fail to do well on an ordinary diet, the restriction of protein may often prove of advantage. Furthermore, protein foods are more costly than the non-nitrogenous foods as sources of energy and where, for economic reasons, the total diet must be limited, the necessary fuel value must be obtained to a larger degree from carbohydrates and fats.

More or less distinct from this question of energy requirement is that of the need of the body for particular building substances. The elements, carbon, hydrogen, oxygen, nitrogen, sulphur, phosphorus, chlorine, sodium, potassium, calcium, magnesium, and iron are all essential in appreciable amounts. Recent studies have shown that many actual dietaries are deficient in some of these substances and that, in particular, a faulty relation between the acid and basic elements may be the cause of serious physiological derangements. Furthermore, it is by no means only the elementary substances which are important but the form of combination in which they occur. The iron in meat for example is in a less available nutritive form than that in milk or eggs. It has been demonstrated that particular amino acids and even particular fats perform a function so peculiar that they are not mutually replaceable. The selection of foods is, therefore, seen to be a problem of complexity and of large importance.

The rational consideration of these problems has been somewhat confused by the popular campaign for "pure foods," in which sensational appeals to prejudice have been more prominent than a knowledge of the principles of nutrition, sanitation, or economics. Honest labelling of foods, as of all other forms of merchandise, is eminently desirable and there is no

difference of opinion on this point. The dangers to health from adulterated foods have, however, been grossly exaggerated, so as to divert attention from matters of much more serious moment and to lead to demands for legislation which would work real harm by restricting the use of safe and economical food-substances. The ordinary adulterants and preservatives are not poisons and their use sometimes makes it possible to furnish nutritious and palatable foods at distinctly lower cost. In such cases they may be regarded as representing advances in the art of food preparation and conservation, provided always that no deception or fraudulent charge based on a different product is permitted.

Far more important than "pure food" is the question of clean food. Polluted water and milk and shellfish and food that has been handled by persons infected with specific maladies like typhoid fever have again and again been the cause of widespread outbreaks of disease and the protection of food products against such dangers cannot receive too much attention. This subject will be referred to again in connection with the general question of the control of communicable disease.

The whole problem of food supply deserves a more detailed and comprehensive and systematic study than it has so far received. There are many signs that the old doctrines of Malthus have a serious application to the life of the present day, although in somewhat modified forms. The progress of civilization intimately depends on the conservation and utilization of food supplies. We must do far more than we have yet done in intensive agriculture, in plant and animal breeding, in pisciculture and regulation of fisheries, and the like. We must improve the methods of food preservation and organize the process of distribution which is still in a primitive state. Above all the individual housewife must be educated in the principles of dietetics and intelligent buying for here as elsewhere ignorance is the cause of most of the evils which beset the human race.

3. In addition to suitable atmospheric conditions and an adequate food supply, the health of the individual depends on such a use of the bodily machine as shall *keep the organs and tissues in normal tone*, and yet free from the harmful effects of overuse. Air, food, exercise, and rest are the four pillars of the temple of Hygeia.

The physical frame of man is essentially a muscular machine. It was developed in relation to a vigorous animal life and the voluntary muscles, which make up more than half the substance of the body, are closely correlated in their function with many of its other organs. Only by active exercise can these muscles be supplied with the blood which they need for nourishment and only by active exercise can the poisonous waste products of their metabolism be swept away. The heart, blood-vessels, and lymphatics, the respiration, the nervous system, and the heat-regulating mechanism are all brought into active exertion and directly benefited by the exercise of the voluntary muscles. The active metabolism created stimulates appetite, digestion, and excretion and there is scarcely a part of the bodily frame which does not benefit in direct or indirect fashion.

For most of us, in the differentiated and largely sedentary life of the modern city dweller, the opportunity for vigorous physical exercise does not come naturally but must be definitely planned for as a means toward the highest health and efficiency. The form it may take must be determined by the time and place limitations of the individual. Exercise should be, so far as possible, of a kind to develop a wide variety of muscles in various parts of the body and not those of the limbs alone. It should be moderate and rational and guarded against overstrain and, in the case of individuals with some constitutional defect, should be planned under expert medical advice. Exercise in the outer air is of course [illegible] and exercise in the form of [illegible] interest is likely to be [illegible] routine of individual [illegible] other, however, it is essential to true health and vigor that provision should be made for the normal functioning of the voluntary musculature.

Quite as essential as exercise is the complementary need of rest. Every cell of the body in its normal activities breaks down its own substance and produces waste products of metabolism. The waste must be removed and the tissue repaired before the work of living can go on. Fatigue of the gland and muscle cells is made good during sleep and, if the period of restoration be not adequate, the accumulation of fatigue from day to day may lead to the most serious results. The nervous system in particular is in our rapid and complex civilization, subjected to severe and taxing effort and the result is too often a nervous breakdown which may be prolonged in its effects.

Aside from sleep, which is the only complete and absolute restorative, other more partial forms of rest and recreation help to make good the wasting effects of vital processes. Like exercise, rest varies widely for the individual according to his physiological needs and the conditions of his life and occupation. For some, the only rest comes through inactivity. For others, more or less strenuous amusement or even a change of work may serve to restore the tired energies, one part of the machine resting while others are in active operation. Monotony, prolonged attention and anxiety are far more serious factors in harmful fatigue than mere hard work. So far as the former two are concerned, the mitigation of the evils attendant on the specialized labor of modern industrialism deserves the serious attention of the euthenist. It has been clearly shown that shorter hours may produce a larger product in many cases and beyond the more obvious regulation of child labor and the labor of women, it would often be well for the manufacturer to minimize overstrain as a measure for the direct promotion of efficiency.

Aside from the establishment of legal standards for factory labor, exercise and rest are largely, but by no means wholly, individual matters. In order that exercise may be possible for the children of the crowded city, parks and playgrounds and recreation centers of considerable variety must be provided. Hand in hand with the material facilities must go definite instruction as to their proper use and all through the public school system and in the ramifications of extramural extension work of various sorts, the principles of exercise and rest should receive their due share of attention. The remarkable work of the Camp-fire Girls is an example of what may be done by a private organization in the promotion of a healthy body and a healthy mind.

4. Air, food, exercise, and rest are the chief positive factors essential to hygienic living. Euthenics is concerned, however, not only with securing these favorable conditions but also with the *protection of the individual against other forces, actively inimical to his existence.* With primitive man the provision of shelter against the elements and the search for food must be supplemented by a constant struggle against wild beasts and against the wild men of other tribes.

Wild beasts do not constitute an important factor in the life of civilized man although in India the tiger and the serpent still take their toll. The passions of men, however, are still evidenced by the considerable part played by homicide in the general death rate. A wise and sympathetic but vigorous and impartial and, above all, prompt inforcement of the law must be supplemented by a serious study of causative factors, environmental and hereditary, if personal violence is to be controlled.

The settlement of private quarrels by physical force is, however, after all an exceptional phenomenon.

In international affairs, however, the stupid brutality of the savage too often reigns and serious and high-minded men argue that such must always be the case and that the only remedy for war is the arming to the teeth of their particular nation, with the understanding that its forces will be always used in the interests of peace and justice. In the past it has been comparatively rare for a nation to go to war in the complete and satisfying belief that it was doing something unjust and wicked, so that the competition in armaments on which Europe and the United States have been embarking as "insurance against war" does not excite very lively hopes of its success. On the other hand there is in all nations an encouraging growth of a more courageous and constructive spirit which holds that the way to have peace is to prepare for peace rather than for war. Disarmament and the elaboration of plans for the judicial settlement of international disputes can be easily accomplished so soon as the political leaders of a few great nations seriously desire that they come to pass.

It is not only with other living things but with the forces of nature and the inanimate machinery of civilization that the euthenist must cope. The losses of life from fire, particularly in the United States, call for vigorous preventive measures in the line of building construction and the regulation of the use of factories and public buildings. Our railroads kill 10,000 people a year and maim nearly ten times that number. Several thousand men die each year in our coal mines and many thousands in our factories and other industrial plants. An examination of the statistics of European countries shows that in all these respects the United States occupies an unenviable pre-eminence.

The responsibility for these conditions seems in all cases to be a double one. On the railroads it is quite clear that archaic and dangerous systems of train despatching often prevail, but it is also clear that such rules as do exist are as often habitually disregarded by the employee. So in the Pittsburgh Survey it was apparent that the carelessness of the worker and the neglect of the employer were equally important elements in the production of over 500 fatal work accidents in a single county in a single year. The control of this problem of industrial accidents demands on one hand the provision of safe working conditions, the installation of approved block signals on railroads, the proper timbering and fire protection of mines, the safeguarding of machinery in factories, and attention to a thousand minor details like yard railroad crossings, slippery floors, unrailed runways, unfenced excavations, and the condition of cranes, tackles, and hoists. On the other hand it is equally essential that the workman should be educated and drilled in the principle of "Safety First" for the root of our special trouble in America lies below the question of employer and employee in a heedlessness and readiness to "take chances" which is almost a national characteristic.

5. There are other dangers which threaten civilized man, far more subtle and far more serious, than the menace to life and limb on the railroad and in the workshop. These are the *microbes of disease*, the invisible parasitic enemies whose activities were so mysterious to our forefathers. "The pestilence that walketh in darkness" was a synonym for an unfathomable infliction of Divine wrath. Even to-day, the mass of people scarcely realize how fully these maladies are under our mastery. Perhaps, as Mrs. Richards says, "it is too much to expect that a sturdy plant of belief should have grown since the days of Edwin Chadwick and Benjamin Ward Richardson (1830–50) less than a century ago, when there were perhaps not a dozen men and women who believed that man had any appreciable control over his own health."

We have clearly learned within the last twenty years that the germs of communicable disease are microscopic animals and plants which differ from other microbes in their habit of life in the tissues or on the surfaces of the human or animal body.

Like other parasites they have acquired a peculiar and definite adaptation to the conditions which exist in the bodies of their hosts and in a corresponding degree they have lost the power to shift for themselves in the world outside. The source of the disease germ is always the body of man or, in certain cases, of some other higher animal. The infected individual may be a sick person or only a "carrier," a well person who is breeding in his body the germs of disease. In each case, however, the infection consists in the more or less direct transfer from one individual to another of a living virus, usually in one of the excretions or dejecta of the body. Furthermore, we have learned that, in the environment outside, the life of the disease germ is a brief and precarious one. A thousand typhoid germs in a lake behave as a thousand men would under the same conditions. A few cling for a while to bits of planks, a few may be strong swimmers, and survive for a time, but most of the men perish quickly and all go under if their exposure is prolonged. The typhoid germs do not drown, but in a few weeks all will have died out, as the men will in a few hours, and throughout the field of epidemiology we find that the danger varies directly with the immediacy of excretal transfer.

This view, that the passage of fresh germs from person to person is the underlying phenomenon in communicable disease, has exorcised many of the specters of the older sanitation. We know for example that the air is not to any appreciable degree a bearer of infection unless polluted by mouth spray in the immediate vicinity of a coughing patient or the like. Contagious diseases are treated in open wards in some of the most modern hospitals, with entire success so long as personal contact is strictly guarded against. Even sewer air has been shown to be so free from excretal bacteria that it could be breathed with impunity except where gross splashing is actually going on. Fomites too, or objects which have been handled by the sick, are dangerous only when recently infected, since the disease germs on such materials quickly dry and perish. The old stories of toys taken from storage after weeks or months and still retaining power of infection are apocryphal and even terminal disinfection after the recovery of a case of communicable disease is regarded by the modern sanitarian as a matter of small moment.

There are on the other hand three important ways in which fresh virulent material is spread from person to person; and these modes or vehicles of disease are food, insects, and direct contact. All these are of vital significance and deserve a brief consideration.

In order that a given article of food may transmit disease it must be exposed to excretal pollution, it must be consumed promptly so that the infection may not die out, and it must be eaten raw. In only a few cases are all these requirements realized. Many foods, like eggs, fruits, and vegetables peeled before eating, are protected against infection from the start. Others, like ice, are purified by storage, while the great majority of foods are rendered safe by cookery which destroys the ordinary disease germs and their toxins. Water, milk, and shellfish are the principal foods which are liable to pollution and are frequently consumed fresh and uncooked and it is these three which have been chiefly implicated in widespread outbreaks of disease. The epidemics of typhoid fever and cholera which have followed the use of sewage polluted water supplies are among the most severe in sanitary history. We have simple and efficient and economical methods of forestalling these dangers in the form of purification by storage, filtration, or

disinfection. So with milk, which not only carries the germs of typhoid fever, scarlet fever, diphtheria, and sore throat from man to man, but transmits tuberculosis from the cow and causes the terrible waste of human life from summer diarrhea. Here the remedy is pasteurization, or the heating of the milk to 140°–155°F. for twenty minutes, a procedure which when properly carried out makes milk an absolutely safe food without in any way impairing its flavor or digestibility. The danger from other substances is proportionately much less than from water or milk. It must be remembered, however, that any food may be infected in the kitchen or the pantry, just before it comes to the table, and that many foods may be subjected, by holding them under improper conditions, to more or less objectionable decompositions. Cleanliness and intelligence in handling and the exclusion, so far as possible, of carriers from culinary processes are always and everywhere of sanitary importance.

The second common mode of transfer of disease germs is by means of insects which have picked up the germs of disease on their feet or bodies or have ingested the blood of infected persons. The house fly may be an incidental carrier of typhoid fever and other diseases in the former fashion and in unsewered districts, particularly in the south, this is a serious sanitary problem. Other diseases, like malaria and yellow fever and a wide variety of tropical diseases, are spread always and only by certain mosquitos and biting flies, the parasite passing through definite stages of its life history in the body of the insect. In all these cases the disease may be controlled by measures directed against the insect hosts. It was the discovery of the insect transmission of yellow fever by Reed, Carroll, and Agramonte which not only led to the conquest of yellow fever in Cuba, but made possible the successful completion of the Panama Canal and has opened up undreamed of possibilities in the development of tropical regions all over the world.

The movement for municipal cleanliness which began when decomposing filth was supposed to originate *de novo* the mysterious miasms of disease has acquired a new and definite purpose through these discoveries. The proper disposal of sewage is recognized as of large importance when water supplies or shellfish layings may be menaced by its presence. The unscreened privy vault has been shown to be a serious danger to health, since by flies and in many other ways disease germs may find their way from its contents to various food supplies. The removal of accumulations of stagnant water which may breed mosquitos is a public health measure of serious consequence. On the other hand, there are many forms of rubbish and many odoriferous nuisances which are of moment only from the standpoint of civic cleanliness and decency and have no appreciable bearing upon the public health.

The most important cause of communicable disease in temperate climates is the transfer of infectious material from person to person by more or less direct contact. Man is by nature an uncleanly animal and the saliva is pretty constantly smeared upon the fingers, while the presence of intestinal bacteria in a fair proportion of cases, as well as the spread of diseases like typhoid fever to nurses and attendants, shows that even bowel discharges are sufficiently abundant to constitute a serious danger. The attention of sanitarians, once devoted to the vague and mysterious possibilities of general environmental infection, are now focused more and more closely upon the infected individual, the original source of all danger. The detection of these foci of infection and the establishment of such a state of isolation as shall prevent the dissemination of disease germs in their excreta is one of the supremely important duties of the health department. In some cases, as in diphtheria and typhoid, it is possible to detect by bacteriological methods even the [illegible] carrier and many outbreaks [illegible] procedure. Often, however, it is impossible to locate these unsuspected carriers until after the harm has been done and in many cases [illegible] identifying them at all. An [illegible] control of communicable disease can be [illegible] through the cultivation in the community at large of an instinct of personal cleanliness, an aseptic sense, which shall automatically keep from the mouth, fingers, utensils, and everything which is not bacteriologically clean; for the mouth is in most diseases the one portal by which infection finds its entrance.

In addition to the sanitary measures which may be taken to keep the germs of disease from the body entirely it is possible to arm the body cells specifically against certain invading microbes, so that those which do enter will be quickly and easily overcome. Vaccination against smallpox, introduced by Jenner at the beginning of the nineteenth century, was the first of these achievements of preventive medicine and its result has been the reduction of the greatest pestilence to which the human race has ever been subject to the status of a medical curiosity. Pasteur placed the artificial control of immunity upon a firm scientific basis and to-day we know that in a wide variety of diseases a vaccine may be prepared, by killing the germs or by weakening their virulence in some way, which, when injected into the body, stimulates its defensive mechanisms so as to produce a more or less complete immunity against the particular parasite used. The most brilliant successes along this line have been achieved in rabies and typhoid fever but in many other diseases, vaccines may be used with more or less advantage for preventive purposes and they are sometimes helpful in raising the resistance of the body toward disease processes already under way. In diseases like diphtheria and tetanus where a powerful soluble toxin is produced by the parasite a high active immunity may be produced in an animal and the blood serum of the animal containing a specific neutralizing antitoxin may be injected directly into the patient so as to check the disease process at its height.

One of the euthenic procedures which has proved of most value in the detection of incipient cases of communicable disease and the prevention of their further dissemination is the organized inspection of school children by physicians and nurses. This original function of school inspection has, however, come to be overshadowed by the opportunities which have been revealed in recent years for the discovery of minor but more prevalent communicable diseases of eye, skin, and scalp and particularly of non-contagious defects in eyesight, hearing, teeth, respiratory membranes, and the like. The good that comes to the community from the timely detection and treatment of these constitutional defects is not easily estimated, but is surely fraught with rich possibilities in the individual soundness of the men and women of the future

Certain diseases to which mankind is subject take such a heavy toll, and require such special measures for their control, that particular organizations have been developed to deal with them more efficiently. A systematic campaign of this kind was first worked out for tuberculosis, which has as its direct aims the provision of sanatoria for treatment and hospitals for the isolation of advanced cases and the education of the people in the principles of hygienic living, which, by building up vital resistance, is the most effective of all measures in combating this disease. In the future it is probable that the movement will extend beyond the individual to the sanitary improvement of tenements and work places, which to-day so often make hygienic living an impossibility. Next in importance to the war against the great white plague

is that which is being waged on infant mortality. The terrible death rate of infants which carries off ten to twenty per cent. of the children born before they reach the age of one year, is due, as Dr. Holt has pointed out, to the twin causes of ignorance and poverty, and the systematic campaigns carried out in Cleveland, New York, and other cities, for the education of mothers in the principles of infant feeding and clothing and care have borne fruits as remarkable as any achieved by modern sanitary science. The social evils of alcohol and the sex diseases are problems of greater complexity; but these too are at least being attacked in systematic and scientific fashion.

The results of the comparatively new art of sanitation have already been so notable as to constitute almost a revolution in the conditions of human life. There are now 200 death beds every day in the city of New York and if the death rate were as high as it was twenty years ago, there would be 130 more. Over one-third of the suffering and death of the last generation has been wiped out by sanitary science and there are new fields of possible achievement opening to us every day.

The application of euthenics in the diverse fields which have been considered requires vigorous and enlightened community action along many different lines. On an isolated farm the family is a more or less independent unit, with its own well, its own cow, and its own vegetable patch. In the city, the individual depends for his existence on a great complex of interrelated forces far beyond his own control. He must rely on public authority for securing the essential things which his more primitive forbears could secure by their own initiative. The art of government becomes far more than a mere mechanism for maintaining peace and order and comes to be a great organization for social and industrial engineering.

It is essential in a civilized community which aims seriously to develop the maximum possibilities of its citizens that a diverse variety of public services should be effectively organized to provide the most favorable environmental conditions. Healthy surroundings for the body (which means clean, cool, moving air and adequate light) must be provided in the home and in the workroom by tenement and factory inspection and in the street by building regulations, good paving, and the suppression of offensive nuisances. Safe water supplies must be provided by the municipality and safe milk supplies guaranteed by the enforcement of efficient pasteurization. All foods, and the places in which they are prepared and handled, must be inspected to maintain a reasonable standard of cleanness. The whole business of food production and food distribution must be supervised to ensure a maximum of efficiency and economy. Excessive industrial strain must be regulated by wise factory laws and park and playground facilities provided for needed exercise and recreation. Communicable disease must be detected and stamped out by isolation at its source. Sewage and other wastes must be so disposed of as not to menace health and the insect carriers of disease must be eliminated by destroying their breeding places. Vaccines and sera must be porvided and their use required, wherever they have been proved to be effective in the prevention or the cure of specific disease.

All these things and many more may be done by the public officials who act as the expert directors of the community in the diverse technical problems which make up our common life. There are many more things, and much more important things, which must of necessity be worked out by the individual citizen in the home or the factory. The maintenance of good air conditions, the selection of a rational diet, the hygienic conduct of life in regard to exercise and rest, the habits of cleanliness which prevent the spread of communicable diseases—these are not things within the direct power of a health commissioner. It is only by educational leadership that he can diffuse these practices among the citizens and it is more by the extent to which this is accomplished that his success should be measured than by any purely administrative act. As Mrs. Richards says in her book which admirably emphasizes the educational aspect of euthenics, "In America, we have learned to use the phrase, 'Big Stick' Authority is exactly that; it is coercion from without. It has partial result in good; the law may be fulfilled because the individual knows he must obey when within the jurisdiction of that law; but if the result is simply obedience to authority and not to the underlying principle, it will not be a force in his life or be continued if by chance he can escape it." In another place she says, "The leaders must show convincingly that the laws which they have discovered may be applied to daily life, but the individual himself must adopt them. When he has been saturated with knowledge, his inertia will break down, his hopelessness give way to its very antithesis, a strong hope for a better future. Every known method must be used by the laboratory to develop this hope into a belief wide enough to reach all members of every section of the community and deep enough to become a vital working principle. Only through a belief strong enough to ride over unbelief and inertia, a belief in the value of science for personal life strong enough to make a wise choice possible, can the will to obtain a better environment be developed."

Education, widespread and persistent and effective education, is the great task of euthenics to-day. The human race has accumulated a great mass of scientific knowledge as to the physical conduct of life but the dissemination of this knowledge by instruction of the child in personal hygiene, of the housewife in domestic hygiene, of the employer and the employee in industrial hygiene, of the citizen in municipal hygiene, is essential if it is to bear fruit.

With all the technical knowledge too must go a diffusion of a social and spiritual impulse to make it widely effective. H. G. Wells says in First and Last Things: "The essential fact in man's history to my sense is the slow unfolding of a sense of community with his kind, of the possibilities of cooperation leading to scarce-dreamt-of collective powers, of a synthesis of the species, of the development of a common general idea, a common general purpose out of a present confusion." The betterment of living conditions is an end toward which advanced men in all ages and in all climes have been blindly and vaguely struggling. To-day the nature of the task has in many of its aspects become so clear as to be concretely and scientifically realizable. We propose to make progress toward this end conscious and purposeful and universal among mankind. THIS IS EUTHENICS.

C. E. A. WINSLOW.

Eve, Paul Fitzsimmons.—Born near Augusta, Georgia, June 27, 1806. He received the degree of Doctor of Medicine from the Medical Department of the University of Pennsylvania, in the spring of 1828. From 1829 to 1831 he prosecuted his professional studies in Europe, part of the time in London, under Abernethy and Johnson, and Sir Ashley Cooper, and the remainder of the time in Paris, under Dupuytren, Larrey, Roux, Velpeau, and others. In November, 1831, he returned to this country, and soon afterward organized the Medical College of Georgia, he himself taking the chair of surgery. He held this position up to the year 1850, when he was made Professor of Surgery in the University of Louisville. During the following twenty-five years he occupied the same chair in the following institutions successively: University of Nashville, Missouri Medical College, and Nashville

Medical College (afterward the Medical Department of the University of Tennessee). His death occurred on November 3, 1877.

Stone, in his Biography of Eminent American Physicians and Surgeons, says of Dr. Eve that he was the first American surgeon to perform a successful hysterectomy and the first to remove the crista galli, and that he had remarkable success as a lithotomist. . . . . He trephined the lateral sinus of the brain, and by tracheotomy and with forceps he successfuly removed a nail from the left bronchus; he introduced a simple cannula needle for applying ligatures and sutures. His contributions to medical literature were very numerous. "No surgeon in the South held a higher position or did a larger practice of surgery than Dr. Eve."

A. H. B.

Evolution.—(L. *evolutio*, an unrolling, from *evolvere*, to unroll or unfold.) The term *evolution* has been employed with various meanings:

1. It was used at first in its true etymological meaning of unrolling or unfolding to describe a supposed method of the individual development of organisms.

2. Later it was applied in a metaphorical sense to the origin of species, where it means simply continuous descent with modification, or the origin of species by the alteration of pre-existing species.

3. Finally, we have the metaphysical meanings of the word when used to designate systems of philosophy that attempt to explain the origin of all things by continuous change. The great exponent of the evolutionary philosophy is Herbert Spencer. The central points in his philosophy are the laws of the indestructibility of matter and the conservation of energy. According to Spencer, the result of these laws is rhythmic motion, manifested everywhere from the dance of molecules to the gyrations of planets, and this produces an alternation of evolution and dissolution throughout the universe. Spencer defines this evolution as "an integration of matter and concomitant dissipation of motion; during which the matter passes from an indefinite, incoherent homogeneity to a definite, coherent heterogeneity; and during which the retained motion undergoes a parallel transformation."

Evolution is included also in the philosophy of Bergson (1911). He covers a smaller field and his view of evolution differs radically from Spencer's. Spencer is mechanistic, Bergson is vitalistic. Bergson tries to establish a distinction between mathematical time as a succession of events and absolute time that is duration. "Like the Universe as a whole, like each conscious being taken separately, the organism which lives in a thing that endures." Bergson's habit of avoiding concise definitions makes it difficult to state the substance of his views in a few words. But perhaps the keynote of his philosophy of "Creative Evolution" may be found in the statement that, "Organic evolution resembles the evolution of consciousness, in which the past presses against the present and causes the upspring of a new form of consciousness, incommensurable with its antecedents"; and in the further statement that, "It might be said of life, as of consciousness, that at every moment it is creating something." He rejects the idea that life is dependent on chemical and physical phenomena, while admitting that they are related. "Vitality," he says, "is tangent at any and every point to physical and chemical forces," but "in reality life is no more made up of physico-chemical elements than a curve is composed of straight lines."

The lack of scientific foundation for Bergson's philosophy and the false analogies upon which it is based have been forcefully exposed by H. S. R. Elliot (1912).

Metaphysics being beyond the scope of the present work, we will confine our attention to the [illegible] logical meanings of *evolution*.

Evolution in Ontogeny.—Modern embryology may be said to have begun with the work on the development of the chick which Harvey described in his "Treatise on Generation" in 1651. By means of a hand lens he was able to trace the development of the chick in a general way back to the beginning of the second day. He found that the embryo arises from the light-colored spot in the yolk, called by Fabricius the *cicatricula*. Harvey saw this dilate and become divided into circles, forming what we now call the *area embryonalis*, and this he compared to the iris of the eye and called the *oculum ovi*. At the end of the third day he discovered a fine line of red around the edge of the spot, "and nearly in its center there appears," he says, "a leaping point of the color of blood so small that when it contracts it almost entirely escapes the eye, when it dilates it shows like the smallest spark of fire. Such is the outset of animal life which the plastic force of nature puts in motion from the most insignificant beginnings." He was unable to distinguish any other parts of the embryo until the fifth day, and he describes in a very interesting way the gradual appearance of the various organs of the embryo as he saw them from that time until the perfect chick is formed.

One of the great generalizations that Harvey made as a result of his observations is known as the theory of *epigenesis*. This is, briefly, that the embryo is built up gradually from a simple beginning by the addition of part to part in a definite order. Harvey regarded the blood as "the first engendered part . . . the source and origin of all other parts . . . which thence obtain their vital heat and become subservient to it in its duties."

It was in opposition to this theory of epigenesis that the theory of *evolution* arose.

Malpighi, working a little later than Harvey, and probably having a better microscope, found that the blood is not the "first engendered part," for he could see an outline of the embryo before the appearance of the "*punctum sanguineum*." This small detail of observation led Malpighi to reject Harvey's whole theory of epigenesis. He asserted, instead, that the embryo as a whole is present in the egg before incubation, that it is *predelineated*. This led to a great discussion which lasted for more than a hundred years. Of course, if the whole embryo is predelineated in the egg, epigenesis is an impossibility; and development must be a process of *evolution*, an unfolding of the pre-existing embryo. The chief exponent of this theory was Bonnet, who carried it out to its logical conclusion (1762), and asserted that development is not only a process of evolution, but also that all germs have existed since the day of creation, and that each embryo contains in similar form the germs of all subsequent generations.

The theory of evolution seems, on the whole, to have prevailed as the generally accepted explanation of development until 1812, when Meckel called attention to a Latin treatise, "Theoria Generationis," published in 1759 by Caspar Frederick Wolff, as the dissertation for his doctor's degree. In this paper Wolff had traced the development of both the chick and certain flowering plants back to very simple beginnings, and he showed that the development is really an epigenesis and not an evolution. This view has been fully confirmed by the vast amount of research in embryology that has been carried out during the latter half of the nineteenth century.

The almost medieval theory of evolution of Bonnet and his friends seems so absurd to-day that it would hardly be worth mentioning if it were not for the fact that the theory has been revived recently in a more subtle form.

To be sure the individual development of organ-

isms, so far as we can see with the eye or with the most powerful microscopes, is clearly a process of epigenesis. But, after all, there is much that still remains invisible, and the utmost limits of our vision include only superficial manifestations of forces working within the protoplasm. May it not, then, be true that the embryo is really preformed in invisible particles within the germ-plasm? May not differentiation be in essence merely the visualization of pre-existing invisible potentialities? If we answer these questions in the affirmative, our explanation of ontogeny is as much evolution as was Bonnet's. There has been much discussion of this subject within the past ten years, but it is so intimately connected with the theories of heredity that it will be more conveniently reviewed in connection with that subject (see *Heredity*).

Organic Evolution.—Usually when one speaks of evolution one means what has been called *organic evolution*, the origin of diversity in the organic world by means of natural processes.

The opposing theory is that of *special creation*. According to this latter view, each species was established in the beginning by a miraculous act of creation. Each species is, then, a distinct and concrete phenomenon of nature. There is but one true classification which is to be discovered, not invented, by naturalists.

From the point of view of evolution, on the other hand, the great fact of nature is the diversity of organic forms, and no sharp line can be drawn between varieties, species, genera, and families. A classification is merely a convenient invention of the human mind to summarize the present state of knowledge in regard to the structure of organisms, and must change from time to time as such knowledge increases. The idea of miraculous intervention is rejected, and the effort is to discover in the organic world the same orderly working of the laws of nature that has been found to obtain in the inorganic world.

In regard to evolution, it must be borne in mind that two questions are involved: First, does the theory of evolution, as a whole, furnish a better summary of our knowledge of organisms than the theory of special creation? In other words, is evolution to be regarded as an historical fact? Second, what are the factors into which the theory of evolution may be resolved, or, how may the fact of evolution be explained as a process?

While there is much difference of opinion among naturalists in regard to the second question, the first is to-day answered by almost every man of science in the affirmative. On the other hand, there are many persons who have not paid especial attention to natural history and who still hold to the doctrine of special creation. Therefore, it may be well to give a brief summary of the evidence on which men of science base their belief in evolution as a fact.

The Evidence of Evolution.—1. In the first place, we have the *analogy of the other sciences*. For the ancients the sun, the moon, and the planets were controlled in their movements by attendant spirits. Until well into the nineteenth century the structure of the earth was explained as the result of a series of catastrophes accompanied by changes in the order of nature. But Newton showed that the movements of the planets could be described by the same formula that describes the falling of a stone, and the result of the labors of Hutton, Lyell, and their successors, has been to show that the structure of the earth may be explained as the gradual effect of forces now to be observed at work upon the earth's surface. In a similar way, in physics and chemistry the supernatural has been replaced by the natural, until the doctrine of special creation, if accepted, would remain the only exception to the general rule that all phenomena of nature are to be explained by natural laws.

When we say "explained" it must be borne in mind that, in reality, science explains nothing. What science really does is to describe phenomena by means of brief formulæ that summarize the greatest possible amount of knowledge. A "natural law" is not an object of nature, it can do nothing. It is merely a human invention to summarize man's experience of the past and his belief as to the future. When we say that a stone falls with the velocity, $v = gt$, we mean that, whenever the experiment has been tried under proper conditions, this formula has been found to describe truly the result, and we have no reason to believe that it will not always be found to be true in the future. And this is all we mean when we say that the stone falls because of the law of gravitation. In ordinary language we are said to have explained the fall of the stone, but, in fact, we do not know what gravitation is, and we know no more *why* the stone falls than we did before. The common error of deifying natural law may be avoided if we remember that a natural law is a description of a sequence of events that may be expected to occur always in the same order under the same conditions, and an event is explained, or "made plain," when referred to its proper place in this sequence.

Now the question before the naturalist is, Shall the factor of special creation be included in the formula descriptive of the diversity of form in the organic world? We have seen that in all the other sciences the supernatural factors have been rejected as superfluous, therefore from analogy it is *a priori* probable this factor should be rejected in biological theory, including the theory of the origin of species.

2. Turning now to the results of observation, it is evident that from the doctrine of special creation it would be impossible to predict anything in regard to the *classification* of animals and plants, except that it might be supposed that species would be fairly distinct. From the theory of evolution, on the contrary, it might be expected that it would be difficult in many cases to distinguish between varieties and species on the one hand, and between species and genera on the other. Moreover, it would be expected that, to show their true affinities, in the classification the species would have to be arranged like the buds on a tree, in which the buds are the species, while the twigs, the branches, and the stem would represent their hypothetical lines of descent. These two predictions are verified in practice, and the theory is to that extent confirmed.

3. The classification of species leads directly to the study of their *geographical distribution*. The theory of evolution assumes that each species began with relatively few individuals in a restricted locality, from which it spread as the number of individuals increased until it reached its maximum extension. Thus far the theory of special creation might agree. But it would deny the further assumption, that each genus was at first a single species which, as it gradually extended its area of distribution, became exposed to different conditions in different parts of this area, and that, as a result of the operation of natural laws, the individuals in these different sections became changed in the course of generations so as to constitute distinct varieties and later species.

As a corollary to this theorem of evolution, we should expect that the more inclusive a group, the wider would be its range. The length of time required for the evolution of an order would probably be greater than for that of a genus, hence there would be more time for migration and, consequently, a wider range.

Another corollary is that there should be a close relation between the affinities of the organisms in any area and the physical barriers separating it from other areas.

The study of geographical distribution confirms these predictions. It is found that, while some

species have a cosmopolitan range, most species have more restricted ranges than the genera to which they belong, and the genera in turn have smaller ranges than their families and orders.

The affinities of species in any region are found, in fact, to depend more upon the position of barriers than upon the climate or other conditions. This is shown by a comparison of the productions of the Northern hemisphere with those of the more isolated areas of the Southern hemisphere. Oceanic islands, as compared to continental islands, furnish also important evidence on this point.

It must not be forgotten, however, that the facts of geographical distribution present some difficulties for the theory of evolution. But, while some of these still remain to be solved, most of them have been cleared up by a study of the past history of the earth and the geological sequence and distribution of organisms.

4. It might be expected that a study of *paleontology* would furnish the very best evidence of evolution, if it were not for the fact that the preservation of organisms as fossils depends on so many factors of chance that the odds against the preservation of any individual, or even any species, are very high, and the odds against its being both preserved and discovered by paleontologists are still higher. Nevertheless, paleontology has furnished much evidence, and, so far as it goes, it all supports the theory.

In the first place, the evidence from paleontology supplements that from the present geographical distribution by showing the geographical distribution in previous geological periods, and thus making it possible to trace the migrations of forms and to explain their present distribution. In some areas there is a marked similarity between species now living on the surface and the fossils found in the underlying deposits. In cases in which the present distribution is discontinuous to a marked degree, as in the marsupials, tapirs, and camels, it has been found that during earlier periods they occupied intermediate areas.

Direct evidence is furnished by the study of the succession of forms in geological time. In general it may be said that, the farther back we go in time, the less differentiated the forms appear. And in a few series, such as the camels, the horses and the elephants, it has been possible to trace very completely the line of descent from a very generalized type to the highly differentiated forms now living. The study of such a series leaves one with very little doubt as to the fact of evolution.

5. But the fossils are not the only source of information in regard to the past history of species. Each individual may give in the course of its development an abbreviated and simplified picture of the history of its race. At least, such is the inference drawn from a large body of fact furnished by the study of *embryology*. It has been found, as a general rule, that the earlier stages in the development of any form correspond to the more generalized, lower, types of the same group. And in some cases, for example, the fishes, it has been shown that the succession of these stages of gradually increasing differentiation correspond with the succession of forms in geological time. This is exactly what would be expected on the theory of evolution. On the theory of special creation one would expect the development of the individual to take place in as direct a manner as possible, unless there is some physical necessity for the indirect methods which give the appearance of recapitulation of ancestral history. That there is no such necessity is shown by the absence of these ancestral stages in the development of many species, while they are present in related forms, and by the fact that two individuals may reach a practically identical adult structure by entirely different modes of development, as, for example, individuals developed from buds and from eggs of the same species (see article *Budding*).

6. Further evidence of the [illegible] is furnished by the [illegible] that are arrested in development and are apparently of no use to the species in which [illegible] are homologous with fully developed functional organs in other, usually lower, [illegible] related groups. The human body [illegible] number of such vestiges. They are perfectly unintelligible on the theory of special creation, and perfectly in harmony with the theory of evolution.

7. The study of comparative anatomy affords also another line of evidence concerning evolution. This is found in the distribution of *homologous organs*. If each species has been created separately there is no reason why organs constructed on the same fundamental plan, that is homologous organs, should not be found in any number of species. But if, on the contrary, the numerous species in any great group have arisen by the diversification of a relatively simple undifferentiated type, then we would expect the species in one group to show their common origin in similarity of plan of structure, and we would expect them to differ in plan of structure from species of another group having a different origin, although their organs might be called upon to perform similar functions.

Now this is just what we do find to be the case. An internal digestive tract is a fundamental characteristic of all animals above the Protozoa, and we can regard it as probably more or less homologous in all species. But when we come to less fundamental structures, such as legs, wings, and eyes, it is found that the homologies between species are confined to their own great groups. For example, although the wing of an insect and the wing of a bird have [illegible] analogous functions, they are not in any degree homologous. On the other hand, the wing of a bird and the wing of a bat, while differing in detail, have the same architectural plan, which is also the same as that of the arm of man and the foreleg of a horse. Thus the fore-limb throughout the vertebrate series is homologous, although differing greatly in function. This is but one of a great many similar facts, all of which go to show that the vertebrates are derived from a common ancestral type. In the same way the eyes are homologous in all vertebrates, and are not homologous with those of any other group. Mivart thought he had found an homology in the eye of the squid. In its optical principles and general form this eye resembles that of a vertebrate very closely. But a careful examination of its mode of development and minute structure shows that it is formed upon an entirely different plan. In another connection Bergson cites a similar resemblance between the eyes of the scallop, Pecten, and the eyes of vertebrates. But in this case also the similarity is only functional; anatomically they are very different.

Looking back over these seven lines of evidence, we find that, while they present some difficulties, these are all capable of explanation from the point of view of evolution; and these lines of evidence support and supplement one another so completely that the man of science appears to be justified in accepting evolution as a fact, provided he can construct a valid theory to explain or describe the method of evolution.

History of the Theories of E[illegible] The idea of evolution appears in the speculations of the "nature philosophers" of the last decade of the eighteenth century and the first decade of the nineteenth. According to Osborn, this is largely due to the influence of the Greek philosophers. At any rate, the idea seems to have been in the air at this time, for several of these men suggested more or less independently of one another that species are not fixed things, but are subject to change, and that their present form is the result of such change. In each case, however, it was more the [illegible] than the formation of one, and what was of scientific

value was often hidden by the fanciful and absurd. The question was chiefly as to evolution as a fact, and little attempt was made to answer the question as to method, as to how evolution could be brought about.

The first consistent attempt to answer this question of method was made by Lamarck in the year 1809 in his "Philosophie Zoologique." According to Lamarck, "the systematic divisions of classes, orders, families, genera, and species, as well as their designations, are the arbitrary and artificial productions of man. The kinds or species of organisms are of unequal age, developed one after the other, and show only a relative and temporary persistence; species arise out of varieties. The difference in the conditions of life have a modifying influence on the organization, the general form, and the parts of animals, and so have the use and disuse of organs. In the beginning only the very simplest and lowest animals and plants come into existence; those of a more complex organization only at a later period. The course of the earth's development and that of its organic inhabitants was continuous, not interrupted by violent revolutions." He not only asserted as others had done that species have developed, but he gave an answer to the question, How? It is a well-known fact that muscles and other parts that are much used grow stronger, become harder, or are modified in some way that is usually of advantage, while parts that are not used tend to dwindle. Lamarck believed that species are subject to a continued transformation by the inheritance of the results of use and disuse. As the use and disuse of organs is determined by the habits of the individual, Lamarck regarded habit as the chief cause of evolution. An animal's wish to do a certain sort of thing and his constant striving to do it resulted in a change of structure in his descendants that would render them better able to do this thing. On the face of it, it seems reasonable enough to suppose that the well-known effects of use and disuse are inherited, and that varieties and finally whole species have arisen or have suffered change in that manner. But, when Lamarck attempted to carry out this theory in detail, he ran into manifest absurdities, as, for instance, when he attributes the long neck of the giraffe to its habit of striving to reach the leaves of trees. It was perhaps as much on account of the number of such absurdities, as on account of the advance beyond its age, that this work of Lamarck's remained for a long time in obscurity, and was not even mentioned by such men as Goethe and Cuvier, although Lamarck held a high rank by reason of his other works, especially his "Histoire Naturelle des Animaux sans Vertèbres," published in 1815–22.

Another Frenchman, Etienne Geoffroy St. Hilaire, arrived at a similar theory of evolution at about the same time Lamarck did, but he did not publish until 1828 and 1830. His theory was the same as Lamarck's, except that he laid less stress on habit and the inherited effects of use and disuse and more on changes in external conditions. His most important contribution is the idea of permanence of sports giving rise to new varieties and species. He attacked Cuvier's theory that the animal kingdom presents four great independent types of structure—radiate, articulate, molluscan, and vertebrate—and attempted to prove that the whole animal kingdom is formed upon a single structural plan. This gave rise to a dispute which culminated in the famous debates of February 22 and July 19, 1830, in which Cuvier, with his superior knowledge of comparative anatomy, came off the victor.

From this time on for nearly thirty years the believers in special creation and the permanence of species rested assured of their position, relying on the wide knowledge and high authority of Cuvier. They little dreamed of the volcano beneath their feet. For the echoes of the famous debate of 1830 had hardly died away when Charles Darwin started on a voyage that was to have for its chief result the greatest revolution in thought of modern times.

When Darwin started on his voyage in the *Beagle* in 1831, he took with him a copy of Lyell's "Principles of Geology," and he was thus predisposed to regard the phenomena of nature as occurring in an orderly and uninterrupted sequence; moreover, there was in this book a discussion of Lamarck's theory, so that this must also have been fresh in his mind. From his autobiography (p. 82) we learn that he had been "deeply impressed by discovering in the Pampean formation great fossil animals covered with armor like that on existing armadillos; secondly, by the manner in which closely allied animals replace one another in proceeding southward on the continent; and thirdly, by the South American character of most of the productions of the Galapagos Archipelago, and more especially by the manner in which they differ slightly on each island of the group; none of the islands appearing to be very ancient in a geological sense." It seemed to him that such facts, as well as many others, could be explained only by the supposition that species gradually become modified. But it seemed to him equally evident that neither the action of the surrounding condition, as Geoffroy St. Hilaire thought, nor the will of the organisms, as Lamarck supposed, could acccount for the innumerable cases in which organisms of every kind are beautifully adapted to their habits of life. In 1837 Darwin began to collect evidence, in the hope of obtaining some light on the subject. So far he had gone no farther than his predecessors. He had found much evidence for a theory of descent, but the question, How? still remained unanswered. In collecting facts he paid special attention to the modifications of domestic species, and soon came to the conclusion that in these cases "selection was the keystone of man's success in making useful races of animals and plants. But how selection could be applied to organisms living in a state of nature remained for some time a mystery."

In October, 1838, Darwin happened to read for amusement Thomas Robert Malthus's "Essay on the Principle of Population" (1803), and then the solution of the problem flashed upon him. Malthus quotes from Benjamin Franklin's "Observations Concerning the Increase of Mankind" (1751) the remark that "there is no bound to the prolific nature of plants or animals but what is made by their crowding and interfering with each other's means of subsistence." He applies this, as Franklin did, to mankind, and he shows, moreover, that man tends to increase in a geometrical progression, and that if it were not for checks on population, the number of human beings on the earth would be doubled at least once in every twenty-five years. And, further, while population tends to increase in geometrical ratio the food supply, according to Malthus, can be increased only at most in an arithmetical ratio. As population tends to increase faster than the food supply, the lack of food soon becomes the principal check to further increase. Darwin, from his long-continued observation of the habits of animals and plants, was well prepared to appreciate the struggle for existence which goes on everywhere as the result of this law of increase, and it struck him at once "that under these circumstances favorable variations would tend to be preserved and unfavorable ones to be destroyed. The result of this would be the formation of new species." Darwin called this the process of *natural selection.* With characteristic caution, he did not even permit himself to write out his theory for a long time, but continued searching for evidence for and against it.

In the meantime, Alfred Russell Wallace made a journey to the Malay Archipelago. Like Darwin, he was much impressed by the evidences that he found for the evolution of species. While in Borneo in

February, 1855, he wrote a paper on this subject that was published in the *Annals and Magazine of Natural History* in the following September. In this paper he stated the law that, "Every species has come into existence coincident, both in space and time, with a pre-existing, closely allied species." This is the next thing to saying that every species has been evolved from a pre-existing, closely allied species. Wallace evidently hesitated to state the law in this form because he had no theory to offer as to the manner in which evolution is brought about. He brought forward the evidence from classification, from geographical distribution, paleontology, and vestigial organs; and the law that has been quoted was the final result of this paper. The question, "How?" still haunted him, however. Three years later, Mr. Wallace was at Ternate in the Moluccas and, while confined to his bed by fever, he was meditating on this problem. The "positive checks" occurred to him—war, disease, famine, and the like—described by Malthus in his "Essay on Population." He saw that these must apply to the animals as well as to man, and he thought of the much more rapid multiplication of animals, and then there suddenly flashed upon him the idea of the survival of the fittest, "that the individuals removed by these checks must be on the whole inferior to those that survive." Three days later a paper embodying this theory was written and on its way to England, addressed, strange to say, to Mr. Darwin, who had been working on this same theory for years. The immediate result was that Darwin was reluctantly persuaded to publish an abstract of his work, together with Wallace's paper, and the two appeared in the *Journal of the Proceedings of the Linnean Society* for 1858 ("Zool.," vol. iii., 1858, p. 45). In 1859 the "Origin of Species" was given to the world and gave the impetus to that great revolution in thought to which we have already referred.

We certainly cannot honor too highly the pure love of truth and devotion to science, uncontaminated by ambition for fame, which we see in these two men, and we are especially called upon to admire the loyal and ungrudging way in which Wallace attributes all the honor of the great discovery to Darwin. It is of interest to us Americans to note that the man who furnished the necessary cue to both Darwin and Wallace, Thomas Robert Malthus, received it in turn from our fellow-countryman, Benjamin Franklin.

We are indebted to Darwin for the first presentation of a theory of evolution that carried with it conviction to the scientific mind. Because it did carry conviction it was attacked with great vigor on all sides, scientific and unscientific alike. The younger generation of to-day can hardly appreciate the bitterness of the struggle between the advocates of tradition and those of the new idea.

As men of science gradually became convinced of the fact of evolution, there arose a calmer discussion as to the method. Some have held that natural selection is the sole factor; others, that it is the prime factor, but that it is supplemented by other factors; then there are the "neo-Lamarckians," who hold that, while natural selection is a factor, it is one of minor importance compared to the inheritance of acquired modifications. We will turn now to a very brief consideration of each of these factors.

Factors of Organic Evolution. 1. *Variation.*—Variation may be defined as deviation from the type of the species, race, or family, or from whatever may be taken as the standard. Without variation there could be no change of type, and variation must, therefore, be at the basis of every theory of evolution.

So long as species were regarded as fixed, immutable objects of nature variations were generally disregarded. Thus, when Darwin began to collect data on the subject he found few recorded observations. While he succeeded in finding much evidence of variability in domestic races, he [illegible] wild races to be relatively [illegible] amount. Wallace was the [illegible] wild species are frequent[illegible] ning with the work of Galton (1889) [illegible] and greatly aided and stimulated by [illegible] Mathematical Contributions to the Theory of Evolution which Pearson began to publish in 1895, naturalists have paid a great deal of attention to variation, and a considerable amount of literature has accumulated on the subject.

It has been found that all characteristics of organisms are subject to variation. Some variations are *congenital*, that is apparently independent [illegible] vironment; while others are *acquired modifications* due to a reaction of the organism to a definite factor in the environment.

Variations may be *abnormal*, that is wide and infrequent departures from the type, such as the horticulturists call *sports;* or they may be *normal*, occurring in varying degrees in a majority of the individuals of the species, as, for example, variations of stature in man. For the first kind De Vries (1905) uses the term *mutation*, the second kind he calls *fluctuations*.

The first data for the quantitative study of variation were obtained from measurements of soldiers, and Quetelet (1846) first applied statistical methods for the analysis of such data and showed their relation to the theory of probability. The first quantitative measurements of variation in wild animals were made by J. A. Allen in 1871. Galton a little later introduced the statistical treatment of variations, and Pearson has shown how they may be subjected to accurate mathematical analysis. The subject will be treated here only as far as may be necessary for the understanding of natural selection. (For more extended treatment, see article *Variation*.)

Most persons regard "chance" as something entirely apart from law—something which cannot be predicted. But the mathematicians have shown long ago that chance is subject to strict mathematical laws. Single events cannot be predicted, it is true, but the general result can be predicted with certainty. For example, Weldon has published the results of four series of experiments in throwing dice. In each series there were 4,096 throws of twelve dice, and at each throw the number of dice having more than three points on the upper side were counted and recorded. The frequency with which 1, 2, 3, etc., dice showed more than three points was tabulated—and the results, when plotted, were found to follow very closely the theoretical curve of chance, which is described by an exact mathematical formula. Now it is found in a large number of cases that the variations in the characters of organisms which can be determined accurately—by counting, as the number of ray flowers in the daisy; or by measurement, as the length of a man's head—when tabulated and plotted occur with the frequencies predicted by the law of chance. So we may say that normal variations occur, as a rule, by chance.

This is best illustrated by an example. In the course of investigations carried on under the direction of the writer, measurements were made of the width of the angle at the apex of the shell in ninety-seven specimens of *Purpura lapillus*, a marine [illegible] common on the New England coast. The results were tabulated as follows:

	Classes.					
Width of angle in degrees	60–65	65–70	70–75	75–80	80–85	85–90
Frequency	3	21	45	24	4	

These results may be represented graphically by the five rectangles in Fig. 2157, where the limits of the class are represented by the width of the rectangle, and the height represents the number of individuals included, or its frequency. It will be noticed that the middle rectangle is the highest and, therefore, represents the most frequent class. This has been called

the modal class, and may be taken as representing the *type* of apical angle for the species. The abscissa of the highest point in the theoretical curve is known as the *mode*. It will be noticed also that the classes having the least frequency are those farthest removed from the mode. By some easy mathematics one may readily obtain the general average, or arithmetical *mean*, of all the measurements, which in this case is 73.26°, and on the diagram (Fig. 2157) is represented by the position of the line Mx_0. The mean of any character may be taken also as the *type* for the species, and this is used much more frequently than the mode as the standard from which to measure variations. We may obtain a rough idea of the variability of a character by observing the extreme *range* of variation from the lowest to the highest value. But this cannot be done very accurately and conveys no information as to the relative frequency of the intermediate values. A better idea may be obtained by calculating what is called the *standard deviation* ($\sigma = \sqrt{\frac{\Sigma(x^2 f)}{n}}$; see article *Variation*). In our example this has the value of 4.36°, and is represented at σ in the diagram. Knowing the total number of individuals measured, the mean, and the standard deviation, it is possible by the use of appropriate formulæ and tables (Davenport, "Statistical Methods") to calculate and plot the corresponding theoretical *normal curve* of chance. This is represented in the diagram by the heavy broken line. This means that if, instead of taking ninety-seven individuals and dividing them into five classes, we had taken a very large number of individuals, several thousand at least, and divided them into very many classes, we should expect to obtain a series of rectangles, the tops of which would follow the broken line; and in our diagram it will be noticed that the straight lines

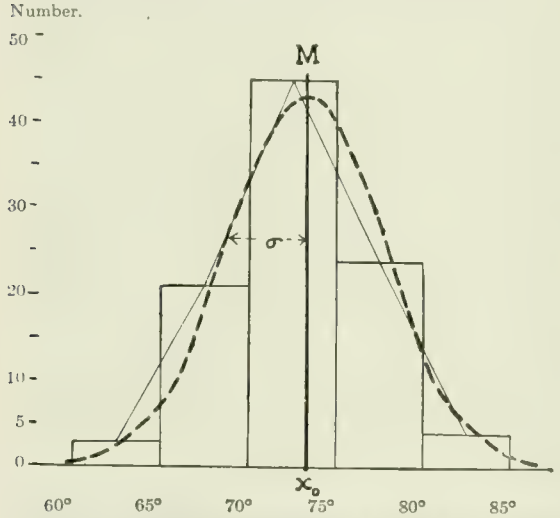


Fig. 2157.—Graphic Representation of a Series of Variations. Variation in the width of the angle at the apex of the shell in *Purpura lapillus*.

connecting the middle points in the tops of the rectangles follow pretty closely the theoretical curve. Thus, although only ninety-seven specimens were taken, much too few for accurate results, it is evident that the different variations in the acuteness of the apex in Purpura occur approximately with the frequency predicted by the law of chance. In calculating this curve it has been assumed that the mode and the mean coincide and that variations less than the mean and those greater than the mean occur normally with equal frequency, so that the curve is perfectly symmetrical. In many cases, however, it has been found that the frequency of variations is best represented by a curve where the mean and the mode do not coincide. In such cases the curve is asymmetrical, and is called a *skew curve*.

In other cases it has been found that there are two or more classes containing a large number of individuals with intermediate classes containing few. The curve plotted from such a series of observations would present two or more modes as the case might be, and would be what is called a *multimodal curve*. An example of such a curve is shown in Fig. 2158, which represents the distribution of variations in the

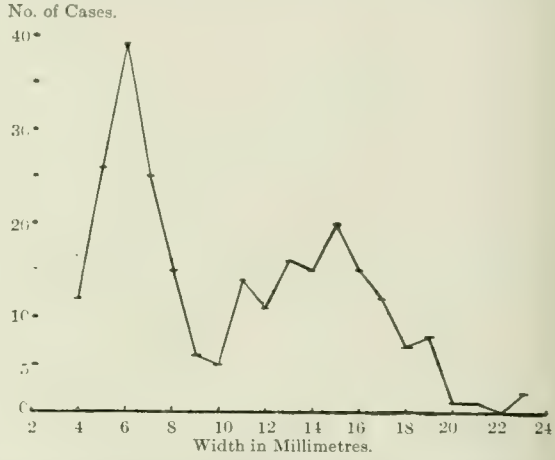


Fig. 2158.—Example of a Multimodal Curve. Variation in the width of the leaf of the cat-tail, *Typha latifolia* and *T. angustifolia*. (After Blankinship.)

width of the leaf of the cat-tail. The data from which the curve is plotted are obtained from measurements of the widest part of the widest leaf in 250 specimens, and are as follows:

Classes.

Width in millimeters.	Number of cases.	Width in millimeters.	Number of cases.	Width in millimeters.	Number of cases.
4	12	11	14	18	7
5	26	12	11	19	8
6	**39**	13	16	20	1
7	25	14	15	21	1
8	15	**15**	**20**	22	0
9	6	16	15	23	2
10	5	17	12		

After allowing for minor irregularities, due probably to the small number of observations, there are evidently two modes, one near six millimeters and the other near fifteen.

This illustrates the distinction between *individual variation* and *racial variation*. So long as the variations are distributed about a single type we have what is called individual variation, and the variability of the species in respect to the character in question is measured by its standard deviation. But where there are several modes—several types about which variations are distributed—we have what may be called racial variation, and this kind of variability is measured by the number of modes and their distance apart. Racial variability tends to divide the species into races, or subspecies. In fact, botanists divide the cat-tails into two distinct species, *Typha latifolia* L. and *T. angustifolia* L. But Blankinship has shown that these two groups grade into one another in all their characters, and this is a good example of the difficulty, often met with, of drawing a sharp line between species.

So far single variations have been treated as if they were isolated objects. As a matter of fact, they never occur as such in nature, for every individual is made up of a great many characters; and the question arises, Is there any relation between the deviation of one character and the deviations of other characters in the same individual? Such a relation is called the *correlation of variations*, and Darwin gave many interesting examples of it. Since then Galton has pointed out a method by which correlation may be studied very exactly, and the degree of correlation may be given mathematical expression. If in a number of individuals character A deviates from its mean M_a by the amount X_a, it is possible to determine what will be the average deviation X_b of the character B from its mean M_b (see article *Variation*).

While much work is still to be done in this line, enough has been accomplished to show that correlations of this kind are common among normal variations; and this is a fact of the highest importance for the theory of evolution.

Heredity.—Heredity is a special case of correlation. It is the correlation between the variations of homologous organs in individuals related by birth, especially those in the relation of parent and offspring. The facts of heredity are of equal importance with the facts of variation. For if this correlation did not exist, or, to use the common metaphor, if there were no inheritance of variations, progressive change of type, evolution, would be as impossible as if there were no variation at all.

The facts and theories of inheritance will be discussed more fully elsewhere (see article *Heredity*). Attention here will be confined to a few facts of especial importance in connection with the subject of the present article.

Heredity may be studied in two ways—one is statistical, the other physiological. The statistical method, initiated by the late Sir Francis Galton, has been carried to a high degree of perfection by Karl Pearson. The modern physiological method was discovered by Gregor Mendel, but remained practically unknown until his results, first published in 1866, were brought to light by Dr. Vries in 1900. This led to great activity in breeding experiments by Bateson, Castle, and many others; and the method has been fruitful of important results. It has been found to be a powerful instrument for the analysis of hereditary characteristics, and by its use a flood of light has been thrown upon the phenomena of organic inheritance.

Galton recognized three chief forms of inheritance: (1) *Blended* inheritance where the character in the offspring partakes of the qualities of both parents, as in stature; (2) *exclusive* inheritance, where the character in the child is like that in one parent, but not like the other, if it differ from the first, as in the color of the eye; (3) *particulate* inheritance, where the child resembles one parent in one character and the other in another character. For example, a child may have its mother's eyes and its father's nose.

From statistical study of these forms of heredity, especially the first, Galton has derived a law of heredity, which Pearson states in the following words:

"Each parent contributes on an average one-quarter, or $(\frac{1}{2})^2$, each grandparent one-sixteenth, or $(\frac{1}{2})^4$, and so on, and that generally the occupier of each ancestral place in the nth degree, whatever the value of n, contributes $(\frac{1}{2})^{2n}$ of the heritage."

Mathematically this would be,

$$h = \tfrac{1}{2}\,H_1 + \tfrac{1}{4}\,H_2 + \tfrac{1}{8}\,H_3 + \ldots \text{ etc.},$$

a geometrical progression approaching a limit = 1, when h = the average deviation of the offspring, and H_1, H_2, H_3, etc., = the deviation in the mid-parent, mid-grandparent, mid-great-grandparent, etc. This is the "Law of Ancestral Heredity," which Pearson has expressed in a more generalized and more exact formula (for which see article *Heredity*).

As to the importance of the law of ancestral heredity, Pearson says: "If [illegible] view of evolution, i.e. if we [illegible] by natural selection [illegible] law which gives us [illegible] the offspring in terms of [illegible] once the foundation stone of biology and the basis upon which heredity becomes an exact branch of [illegible]

The physiological method of [illegible] has given us the Mendelian theory of heredity, which is applicable primarily to Galton's exclusive and particulate forms of inheritance. This theory includes three principles, which, as stated by Castle (1911), are "(1) The existence of *unit characters*, (2) [illegible] in cases where the parents differ in unit characters, and (3) *segregation* of the units contributed by the respective parents, this segregation being [illegible] among the gametes formed by the offspring.

The meaning of this can be understood by considering an actual case. If a black guinea-pig of pure race be mated with a white one, all the offspring will be black, *a*, Fig. 2159. Black is thus said to be a *dominant* character, while white is *recessive*. The two characters, black and white, are said to be alternative characters, or *allelomorphs*. The first generation of offspring is indicated by the symbol F_1, and subsequent generations by F_2, F_3 etc. If the F_1 generation be bred together, the F_2 generation will contain both black and white individuals in the proportion of three black to one white, *b*, Fig. 2159. If the white ones are mated together all their young will be white; but when the blacks in F_2 are mated together, some pairs will have all black offspring, while others will have both kinds in the proportion of three black to one white.

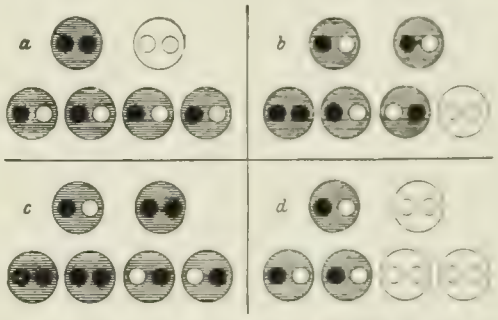


FIG. 2159.—Diagram of Mendelian Inheritance. [illegible] circles indicate individuals the smaller [illegible] each square the lower row indicate offspring [illegible] parents, which are: *a*, a pure dominant [illegible] heterozygous dominants; *c*, a heterozygous [illegible] dominant; *d*, a heterozygous dominant [illegible] Mellison.)

These results are explained by supposing black and white to be a pair of alternative *unit characters* and that in the F_1 generation these characters are [illegible] *gated* so that the eggs or spermatozoa, [illegible] of each individual are of two kinds in equal numbers, half bearing a *factor* for white and half for black. This being the case, if fertilization is at random the chances are that, in the long run, in one-fourth of the unions both gametes will be dominant, in one-fourth both will be recessive, and in half one gamete will be recessive and one dominant. The result is indicated graphically at *b* in Fig. 2159. The new individual, *zygote*, formed by the union of two gametes bearing like factors is said to be *homozygous* for the character in question; if the factors are unlike, it is *heterozygous*. All of the F_1 generation in the case of the guinea-pigs will be heterozygous because the unlike parents are pure bred, and the young are all black because black is dominant over white. In the F_2 generation all the white individuals are homozygous recessives. One-third of the black ones are homozygous dominants, and if bred together will breed [illegible]

while two-thirds of them are heterozygous and will have some white offspring. The truth of the theory of segregation can be tested by varying the experiments. If two blacks of the F_2 generation one homozygous and one heterozygous be mated the offspring will all be black; but when these are bred together, half will breed true and half will not, *c*, Fig. 2159. If a white guinea-pig be mated with a heterozygous black instead of a pure-bred one, the offspring will be half black and half white, but the black ones will not breed true, *d*, Fig. 2159. Dominance has been explained very simply by the "Presence and Absence" theory. "On this theory the dominant character of an alternative pair owes its dominance to the presence of a factor which is absent in the recessive" (Punnett, 1911). A fuller treatment of the Mendelian theory will be given elsewhere (see *Heredity*). We need to note at this point only, that the theory has been the means of bringing to light many facts which have important bearings upon the theory of evolution.

The Struggle for Existence.—With the struggle for existence we come to the first of the distinctively Darwinian factors of evolution.

Darwin's definition is as follows. He says: "I should premise that I use this term in a large and metaphorical sense, including dependence of one being on another, and including not only the life of the individual, but success in leaving progeny. Two canine animals, in a time of dearth, may be truly said to struggle with each other which shall get food and live. But a plant on the edge of a desert is said to struggle for life against the drought, though more properly it should be said to be dependent on the moisture. A plant which annually produces a thousand seeds, of which only one of an average comes to maturity, may be more truly said to struggle with the plants of the same and other kinds which already clothe the ground. The mistletoe is dependent on the apple and a few other trees, but can only in a far-fetched sense be said to struggle with these trees, for, if too many of these parasites grow on the same tree, it languishes and dies. But several seedling mistletoes growing close together on the same branch may more truly be said to struggle with each other. As the mistletoe is disseminated by birds, its existence depends on them; and it may metaphorically be said to struggle with other fruit-bearing plants, in tempting the birds to devour and thus disseminate its seeds. In these several senses, which pass into each other, I use for convenience's sake the general term struggle for existence" ("Origin of Species," 6th ed. vol. i., p. 78).

Wallace uses the term without giving a definition. In his essay of 1858 he says: "The life of wild animals is a struggle for existence. The full exertion of all their faculties and all their energies is required to preserve their own existence and provide for that of their infant offspring. The possibility of procuring food during the least favorable seasons, and of escaping the attacks of their most dangerous enemies, are the primary conditions which determine the existence both of individuals and of entire species."

This term, struggle for existence, is a convenient one, and it conveys a very vivid impression as to what takes place. But it may convey a false idea unless we are careful to bear in mind the metaphorical character of the expression. It may help us to do this if we can find for this term a definition which in itself shall be free from metaphors.

Spencer has defined life as "the continuous adjustment of internal relations to external relations" ("Principles of Biology," 2d ed., vol. i., p. 99). So long as the external relations are favorable, this adjustment is made easily. When they become unfavorable it is made with difficulty, and when it becomes impossible the organism dies. Therefore we may define the struggle for existence as the tendency of organisms to preserve a continuous adjustment of internal relations to unfavorable external relations.

The meaning of this will be more clear when we consider what are these unfavorable external relations in which life becomes a struggle for existence. They may be classified under three divisions: (*a*) adverse physical conditions, (*b*) enemies, and (*c*) competition.

a. The Struggle against Adverse Physical Conditions.—Conditions that are adverse for one species may be favorable for another. Thus the polar bear is unable to live on the hot sands of the Sahara, and the polar ice fields would be equally fatal to the lion. A fish cannot live in the air, nor a bird under water. So what constitutes an unfavorable physical condition depends largely upon the constitution of the organism that meets it.

There are doubtless large numbers of individuals and species which, so long as they remain in their native habitat, never have to contend with adverse physical conditions. Such is true, for example, of the majority of dwellers in the sea, and it applies equally well to the inhabitants of many tropical lands. The islands of the Antilles with their abundant rains, and even, warm temperature, are as favorable as possible for life. The only unfavorable condition is the occasional hurricane, when the rivers "come down," as they say, in irresistible torrents and the wind tears huge trees up by the roots, while the seas dash against the shores with appalling fury. Except for these infrequent catastrophes, the processes of life are favored continually by the physical conditions on land as well as in the sea.

It is in our own temperate region, with its extremes of heat and cold and sudden changes from moisture to dryness, that the adjustment of internal relations to external relations is attended with difficulty. We see this adjustment taking place annually at the time of the falling of the leaf, when the trees prepare themselves to withstand the frosts of winter. The leaves are cut off by an ingrowth of bark. The absorption of water is suspended, and the protoplasm becomes concentrated in the cells already heavily laden with starch. The embryonic tissue is confined to a thin layer under the bark and to small areas in the buds protected by thick envelopes, often lined with down, and varnished on the outside; and the cells of other parts acquire a thick wall of cellulose which renders them incapable of further growth. Thus in the cool days of fall the trees prepare to resist the freezing of winter, and usually this is successful. But sometimes it fails.

The summer of 1879 in England was cool and damp so that the new wood was not properly matured. This was followed by an unusually severe winter, and all over the country thousands of perennial plants were killed or severely injured by freezing. In one locality every common shrub was killed to the ground (Henslow, "Frost Report," 1887). In this country it happens frequently that warm days in early spring tempt the trees to throw off their winter protection, and send forth the young shoots and flower-buds. Then comes a late frost, and all the growing parts are killed.

But extreme cold is even more disastrous to animals. Darwin says: "I estimated (chiefly from the greatly reduced numbers of nests in the spring) that the winter of 1854–55 destroyed four-fifths of the birds in my own grounds." After the great storm of February 1, 1898, Professor Bumpus found 136 sparrows lying helpless upon the ground in Providence, of which sixty-four were dead or dying.

The effects of drought upon animals as well as plants are so well known that they need not be described.

b. Enemies.—Darwin regards extremes of cold and drought as probably the most effective of all checks on population. But the depredations of enemies constitute a check which is even of more universal effect.

Ernest Thompson Seton says: "The life of a wild

animal *always has a tragic end*." There is hardly an animal or a plant, from the humblest protophyte to man himself, that is not subject to the attacks of other organisms. Herbivorous animals feed upon the plants, and these animals in their turn form the food of carnivorous species. Those that escape being devoured in this way, and successfully resist the effects of climate usually at last fall a prey to the inroads of bacteria or other parasites.

Plants are particularly subject to destruction in the early stages of their growth. Darwin dug and cleared a piece of ground three feet long and two feet wide, and then marked all the seedlings of the native weeds as they came up, and out of the 357 no less than 295 were destroyed, chiefly by slugs and insects ("Origin of Species," vol. i., p. 83).

Judd says: "It is not at all uncommon for a crow or blackbird to eat from 30 to 50 seeds of smartweed or bindweed, or a field sparrow 100 seeds of crab grass, at a single meal. In the stomach of Nuttall's sparrow were found 300 seeds of amaranth, and in another 300 seeds of lamb's quarters, a tree sparrow had consumed 700 seeds of pigeon grass, while a snowflake from Shrewsbury, Mass., which had been breakfasting in a garden in February, had picked up 1,000 seeds of pigweed" ("Year Book, United States Agricultural Department," 1898, p. 222). Professor Beal has estimated that in the State of Iowa the tree sparrows alone destroy annually about 1,750,000 pounds, or 875 tons of weed seeds (*l.c.*, p. 226).

These seed-eating birds are in turn preyed upon by the various hawks and owls.

In the sea, plants form the food of few species except the most minute animals. A vast majority of marine species are carnivorous, and the destruction is enormous. Brooks gives a vivid picture of this struggle ("Foundations of Zoology," pp. 220–224 and 231–233). Speaking of the inlets among coral islands he says, "Nothing could illustrate the fierceness of the struggle for food among the animals on a crowded sea-bottom more vividly than the emptiness of the water in coral sounds where the bottom is practically one enormous mouth."

Equally, if not more, important than the actively predaceous enemies, are the parasites. Some are directly injurious, producing disease; while others, like the blood-sucking insects, may cause the destruction of their hosts by carrying disease germs to them.

c. Competition.—The tendency of organisms to increase in geometrical ratio, if not held in check by other causes, will ultimately cause a severe competition, and this constitutes the third class of checks on population.

Competition may be between individuals of the same species (*intraspecific*) or between different species having similar habits (*interspecific*). It is well illustrated in the forests, where each tree that reaches its full growth is, according to Pinchot, "the survivor of hundreds (or sometimes even of thousands) of seedlings."

An example where interspecific competition has had a marked effect on the flora is quoted by Wallace (pp. 20–22) from M. Hansten-Blangsted, who gives an account of the struggle between the trees in the forests of Denmark. The chief combatants are the beech and the birch, the beech being everywhere successful in its invasions.

But we need not go to Denmark to witness a struggle of this kind. In Virginia, when a field is abandoned, trees soon spring up of all kinds, but the pines by virtue of their more rapid growth and dense shade, soon acquire the ascendancy. Many "old fields" are to be seen there where the furrows of the last crop of corn are still visible, and the ground is covered with a thick growth of young pines. Many of these die while still small, and among them may be found a few slender oaks, chestnuts, and tulip trees. If the pines are cut, or if they are allowed to grow old and fall down with decay, they [illegible] by the longer-lived oak [illegible] So that it is a common [illegible] follow pines."

Another case in point is an experiment of Darwin's. He marked out a little plot of [illegible], four feet, and allowed the plants to grow up freely. The result was that out of twenty species growing there nine perished ("Origin of Species," vol. i., p. 83).

Among animals the birds show especially the effect of competition. In some species each pair requires a certain area for a feeding ground, and drives off all others. The English sparrow is said to be responsible to a considerable extent for the decrease of our native birds, and according to a writer in *Nature* (Allchin, January 19, 1899, p. 271), this same sparrow has had a similar effect upon the swallows and martins in England.

The black rat, *Mus rattus*, was formerly the common house rat of Europe and was introduced into this country by the early settlers, but at present it is rare, having been nearly exterminated in competition with the brown wharf rat, *M. norvegicus*. C. S. Brimley (1912) states that up to 1909 the roof rat *Mus alexandrinus*, was the common species in Raleigh, N. C. That year the first wharf rat was seen. In 1911 this species suddenly became very numerous, and appears to have driven out the roof rat.

The efficiency of competition in checking increase is shown when the competition is lessened by an enlargement of the food supply. Most of the waves of life that are mentioned below are due to such an advantage rather than to protection from enemies.

d. Effect of the Removal of Checks.—The enormous destruction caused by these checks on population may be realized to some extent if we consider the birth rate.

It may be stated as a general rule that the birth rate in existing species is proportional to the rate of destruction. Thus the petrel, which nests on inaccessible cliffs and has few enemies, produces but one egg at a time. While the lobster, whose young are exposed to the attacks of innumerable enemies from the time they are hatched, produces from 3,000 to 90,000 eggs. (The largest number found by Herrick was 97,440, "The Lobster," p. 51.) A single carrion fly is said to produce 20,000 living maggots. These reach full size in five days, and the pupa stage lasts five days. It has been estimated that a single fly could produce in three months one hundred millions of millions of millions (Wallace, "Darwinism," p. 25). The common mosquito (*Culex pungens*) lays from 200 to 400 eggs in a bunch. These hatch in sixteen hours. Under favorable conditions the larvæ reach the pupa stage in seven or eight days. This stage lasts two days. Thus one pair of mosquitoes may produce 400 adult offspring in less than ten days. In a few days more these are ready to lay eggs in their turn.

According to Merriam, the house sparrow produces annually five or six broods of four to six each. Assuming an average of 24 young per annum, with sexes equally divided, the produce of a single pair in ten years will be 275,716,983,698 ("Agricultural Report," 1886).

The elephant is said to be the slowest breeder of all animals. Yet Darwin has estimated that if an elephant lives 100 years and produces 6 young ones, in 750 years the produce of one pair would equal 19,000,000 elephants. Man is also an extremely slow-breeding animal, yet the human population tends to double in about twenty-five years.

The power of rapid multiplication is well illustrated by the waves of life that sometimes sweep over a country. A striking example of this phenomenon is the rapid increase and enormous migrations of the arctic lemming, so vividly described by Brehm. (Brehm, "From North Pole to Equator," 1896, pp. 74–76).

Hudson describes a similarly rapid increase of mice

on the Pampas of South America, which was finally brought to a close by a drought and the increase of enemies ("Naturalist in La Plata," p. 59, *et seq.*).

This country is subject to periodic waves of locusts and chinch-bugs, which swarm at such times in hundreds of thousands and do enormous damage to crops (Webster, "The Chinch-Bug," 1898). With the introduction of irrigation and forage plants in the far West, the jack-rabbits have increased rapidly and become a pest. In California during the ten years from 1888 to 1897, 494,634 jack-rabbits were killed in "drives," and yet the total number living was not seriously diminished (Palmer, "Jack-Rabbits," 1897).

The power of rapid multiplication is also well illustrated by the effect of introducing animals and plants into a new country. If the climate be favorable, the introduced form, freed from its natural enemies, may often increase amazingly.

Many of our common weeds, like the ox-eye daisy and the so-called Russian thistle, are good examples of this. Wallace gives a number of cases ("Darwinism," p. 28) of the rapid spread of European plants introduced into South America, New Zealand, and other places.

The common European rabbit has become a pest in Australia and New Zealand. The rabbits were first liberated near Melbourne about 1864, and later in Tasmania and New Zealand. They multiplied so rapidly that in 1879 the legislature of South Australia took action for their destruction, and the matter was taken up soon after in New South Wales, Queensland, New Zealand, and Tasmania. But in spite of all efforts to destroy them, they continued to multiply. Between 1873 and 1898 New Zealand exported two hundred million rabbit skins.

Another example of the rapid increase of an introduced animal is afforded by the Indian mongoose in the West Indies. But at our very doors we have an equally good example in the house sparrow. The first successful importation was made into Brooklyn in 1852. The birds were introduced into Portland, Me., in 1854, and into Providence, R. I., in 1858, some escaping in Boston. Between 1863 and 1870 they were imported into eight cities, one lot of one thousand being sent to Philadelphia. Between 1870 and 1880 it is estimated that the range of this species had been extended by 16,000 square miles (Palmer, 1898), and it has continued to spread. Merriam estimates the rate of spreading of the sparrow as follows ("*Agri. Rept.*," 1886, p. 238):

	Square miles.
1870–75	500
1875–80	15,640
1880–85	500,760
During 1886	516,500
Yearly average United States and Canada	69,000

e. Complexity of the Struggle.—In order to understand the results of these factors in the struggle for existence, it must be remembered that, as a rule, the relations of organisms to one another are highly complex; so that any change in the environment of one species is apt to affect a host of others. Thus, according to Lintner, the English sparrow protects the tussock moth (*Orgyia lincostigma*) by driving away its enemies, the robin, oriole, and cuckoo, the only birds that can feed upon the hairy caterpillars, and thus the sparrow indirectly injures the elms and other trees ("*Agric. Rept.*," 1886). The classical example of this is Darwin's one of the relations of cats to the crop of clover seed.

Wallace quotes an example from Sir Charles Lyell. He says: "If, by the attacks of seals or other marine foes, salmon are reduced in number, the consequence will be that otters living far inland will be deprived of food and will then destroy many young birds or quadrupeds, so that the increase of a marine animal may cause the destruction of many land animals hundreds of miles away." Another example of complexity of relations between organisms is given by Darwin who shows how the enclosure of several hundred acres of barren heath and the planting of fir there had changed the entire fauna and flora of the enclosed area.

These examples are enough to show how very complex are the relations of organisms to one another. We see how a change in the environment of the salmon produces a change in the environment of land animals far away, and how the introduction of a single tree and the exclusion of cattle profoundly affect a host of other organisms. This gives some idea of the complexity of the phenomena to be considered in a discussion of the origin of species.

4. *Natural Selection.*—The facts of variation, inheritance, and the struggle for existence lead, as Darwin and Wallace pointed out, to the *a priori* assumption of the theory of natural selection. If individuals differ in their characteristics, and if there is a struggle for existence in which many perish, then there may be a correlation between the death rate and certain structural or physiological peculiarities, that is, we shall have a survival of the fittest, or better, an elimination of the least fit. But in order that new species may result, not only must the favorable peculiarities of the survivors be transmitted to future generations by inheritance, but other conditions must be fulfilled which we will now consider.

In the first place, as indicated in the preceding paragraph, it by no means follows that there is any necessary relation between destruction and any structural or physiological peculiarity. A flood, a tornado, a forest fire may destroy all in its path. In such a case the destruction is purely fortuitous, or non-selective. On the other hand, if a number of persons are exposed to an infection, say typhoid, to which they present different degrees of susceptibility, then those which possess those physiological characteristics that give susceptibility to the disease in the greatest degree will be those that die, and we shall have then a selective *death rate.* It may be noted in passing that a death rate which is selective in regard to one character may be fortuitous in respect to another, unless the variations of the two characters are correlated.

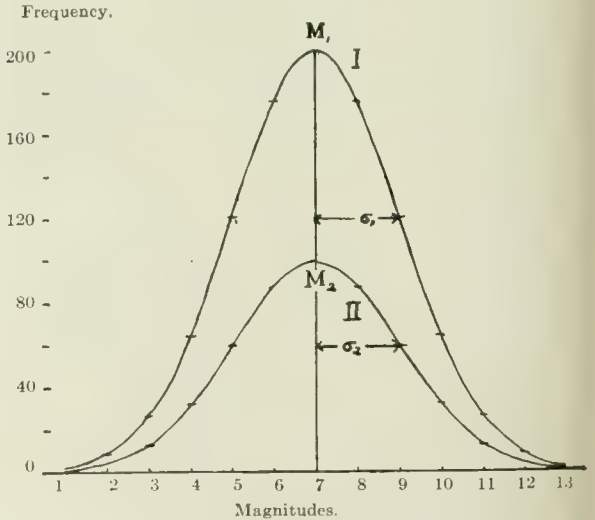


FIG. 2160.—Fortuitous Destruction of 500 in 1,000, Normal Curves. *I*, Birth curve; *II*, survival curve.

Let us consider now what the effect of these two kinds of destruction would be upon the curve of variation. Where there is no destruction, and all that are born survive, we may call the curve the *birth curve*, and its mean the *birth mean.* While the curve obtained after destruction had taken place would be the *survival curve*, and its mean, the *survival mean.* Now

the effect of purely fortuitous destruction would be to give a survival curve that would be exactly like the birth curve except that it would be flatter, and the birth mean and the survival mean would coincide. Such a case is illustrated by Fig. 2160, where the upper line (*I*) may be taken to represent the birth curve of say a thousand individuals in a certain locality, and

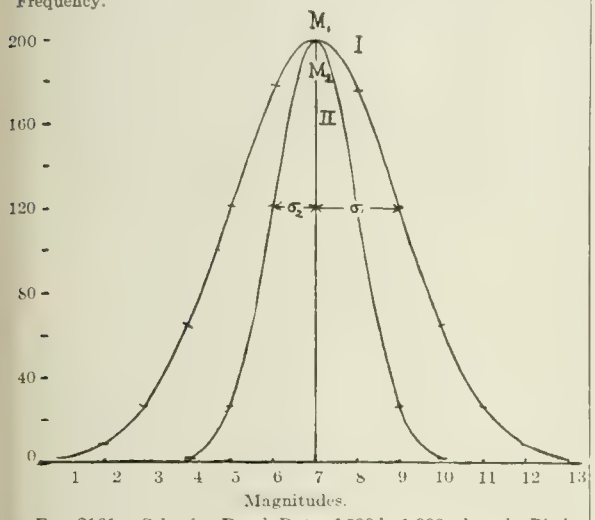


Fig. 2161.—Selective Death Rate of 500 in 1,000 when the Birth and Survival Means Coincide, Normal Curves. *I*, Birth curve; *II*, survival curve.

the lower line (*II*) would be the curve after a fortuitous destruction of half the number. (If percentages were used instead of absolute numbers, the curves would be exactly alike.)

The effect of a selective death rate upon the birth curve would depend upon whether the cause of death is a constant factor of the environment or a new one. If it be a constant factor, it is probable that the species has become adjusted to it. In this case the most

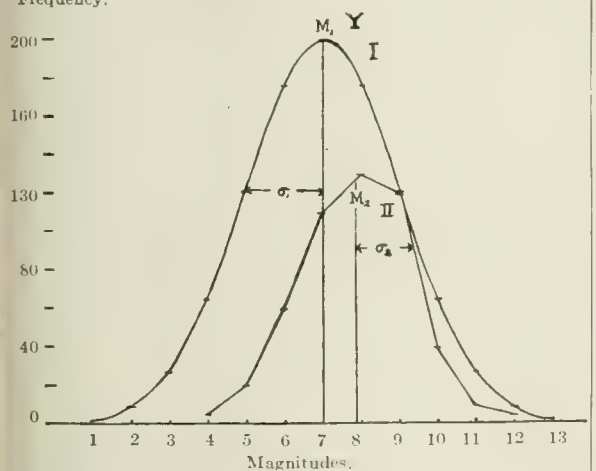


Fig. 2162.—Selective Death Rate of 500 in 1,000 where the Birth and Survival Mean do not Coincide. *I*, Birth curve, normal; *II*, survival curve, purely imaginary.

favorable variation of any character affected by this condition will be represented by the mode, and probably the mean, of the birth curve. Elimination will cause a decrease of variability, so that the survival curve will be steeper on the sides than the birth curve (Fig. 2161). But the position of the mean will not be changed, and there will be no evolution. On the contrary, the effect of natural selection here will be, if anything, to make the species more stable.

It is only when the species [illegible] to the cause of death that [illegible] tion to produce evolution. Then the birth mean will not coincide with the most favorable variation, and the effect of elimination will be to decrease the variability to a greater extent upon the less favorable side than on the other and thus to shift the mean, as in Fig. 2162. This is a purely imaginary example, where the most favorable value of the character measured is supposed to be 9. It will be noticed that the effect of elimination here has been to shift the mean from 7 to 7.88, that is toward 9, and the variability is decreased as shown by the smaller value of the standard deviation, σ_2, which is 1.46 instead of 2. The survival curve is also skew, while the birth curve is supposed to have been symmetrical.

So far we have dealt with the effect of selection upon the first generation only. Of course, fortuitous destruction will have no effect upon the type or variability of the next generation, for the type and variability of the parents have remained unchanged. A selective death rate symmetrical on both sides of the birth mean will not affect the type and will have but a slight effect upon the variability, for Pearson has shown that selection for an indefinite number of generations cannot reduce the variability more than eleven per cent. But where the most favorable value of a character does not coincide with the birth mean, then there will be a change of type, the rapidity of change depending upon the severity of the selection. From the law of ancestral heredity Pearson has calculated the probable effect of perfectly rigorous artificial selection. His results are given in a table, from which it is possible to calculate the curves of six successive generations where the parents selected have a given deviation from the original mean of the population. Fig. 2163 illustrates such a case, where the mean of the population is represented by $M = 0$, the standard deviation is $\sigma = 1$, and the parents for each generation are supposed to have the selected character of the value $H = +2$, or twice the standard deviation. Then the average deviation of the first, second, third, etc., generations of offspring from the original mean of the population will be represented by the distance from M to the ordinates h_1, h_2, h_3, etc. It will be seen that the regression becomes less in each generation until, in the sixth, h_6 almost coincides with H. In other words, if it were possible to make this rigorous selection, we might expect at the end of the sixth generation to obtain a new race that would breed true about a mean differing very little from the selected value.

Turning now from *a priori* considerations to observed facts, what evidence is there that natural selection has actually been a factor in evolution?

First, there is the observed fact of a selective death rate. To say that where the death rate depends upon individual peculiarities the fittest will survive in the struggle for existence, is a truism, for our only means of judging of fitness is the ability to survive. But first we must have evidence that there is some relation between survival and the possession of some characteristic, and, second, that the death rate as a whole is selective. In order to be of value this evidence must rest on quantitative data discussed by correct statistical methods. A considerable body of such evidence has now accumulated.

From measurements made by Thompson and himself in successive years, Professor Weldon came to the conclusion that in the crabs, [illegible] in Plymouth Harbor, England, the frontal breadth of the carapace was becoming narrower from year to year. Seeking a cause for this he found it to be probably the increase of sediment in the harbor, due to the building of a breakwater, which hinders the flow of the tides. To test this theory, he placed a number of crabs in aquaria with a considerable quantity of china clay,

like the silt in the harbor, suspended in the water. A number of crabs died, and at the end of the experiment the dead crabs were separated from the living, and all were measured. It was found that the survivors had distinctly less frontal breadth than the dead crabs.

If this selective destruction is continually going on in the harbor, then the crabs protected from the action of the silt during a portion of their lives should show a greater average frontal breadth than the wild crabs of the same age. A number of crabs were kept in aquaria with clean sea-water until they moulted. When the shell was hard they were killed and compared with wild crabs of the same age. It was found, as expected, that the frontal breadth of the protected crabs was greater.

The great storm of February, 1898, enabled Bumpus to study a similar case among the house sparrows (*Passer domesticus*). During the storm in Providence 136 birds were picked up in a helpless condition. When brought into the laboratory 72 of these revived and 64 died. A number of measurements were made upon each bird of the two lots, and it was found that the mean of surviving birds differed perceptibly in many dimensions from the corresponding mean of the dead ones. Moreover, the dead birds showed a greater average deviation from the mean than the surviving ones.

Harris (1914) has discovered a selective death rate in the common garden beans, *Phaseolus vulgaris*, and the garden peas, *Pisum sativum*, in relation to the weight of the seeds. In his first study he came to the conclusion that this selection has no effect on the mean, but that the variability is decreased. In other words, the medium seeds of each generation stand a better chance of developing into mature plants than do either the very light or the very heavy ones. This would give the type of selective death rate illustrated in Fig. 2161. His later studies show, however, a tendency in some strains toward a shifting of the mean. In some the seeds that survive are on the average heavier, in other strains lighter, than the total average of the seeds planted. In these cases the results would be illustrated by a diagram like Fig. 2162.

W. L. Tower (1906) has found that in one species of beetle probably fifteen per cent. of the population is eliminated during the process of molting, ecdysis, largely because of failure to rupture the integuments.

In these cases single characters were studied in relation to the death rate. It would be more to the point if we could correlate the sum of the peculiarities of the individual as a whole with his chances of death, for natural selection acts upon whole individuals, not upon single characters. Pearson has demonstrated a very ingenious method of doing this for man. If there were no natural selection, the whole death rate would be non-selective, fortuitous; on the other hand, natural selection would reach its maximum efficiency when the death rate becomes wholly selective. In nature the death rate would be usually partly selective and partly non-selective, and the problem is to determine what proportion of the total death rate is selective. In Pearson's method "no attempt is made to select any particular organ, but we take pairs of individuals having some general resemblance in their whole complex of organs and characters, and correlate their fitness for surviving under practically the same conditions of life. Now pairs of relatives or members of the same family are precisely such individuals. If there were no selective death rate there would be no correlation between the ages at death of, say, brothers. On the other hand, if there were no non-selective death rate we might reasonably suppose duration of life would be determined by the law of ancestral heredity," and we should expect the correlation between the durations of life of pairs of brothers to be the same as that observed in the case of stature and other characters.

From a study of one thousand pairs of brothers recorded in the peerage Pearson found that of the total death rate eighty per cent. was selective. Comparing fathers and sons, the result was sixty-five per. cent. A number of later studies on natural selection in man are summarized by Harris (1914). Among these perhaps the most important is the work of E. C. Snow (1911) on the death rate of children. The general result is to leave no doubt that the human death rate is selective.

The second line of evidence is one that especially meets the objections of the advocates of the theory of special creation. This is that it is impossible to find throughout the whole range of the animal and vegetable kingdoms a single structure or function developed in one species for the exclusive benefit of another.

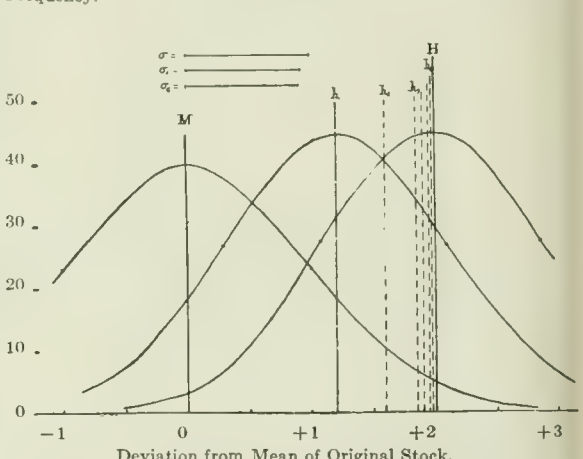


FIG. 2163.—The Effect of a Rigorous Artificial Selection during Six Generations, where the Selected Parents of each Generation Deviate from the Mean (M) of the Original Stock by Twice its Standard Deviation (H). The broken lines h_1 h_2 h_3 . . . h_6 represent the position of the means of the first, second, . . . and sixth generations of offspring. When $M = 0$ and $H = 2$, $h_1 = 1.2$, $h_2 = 1.6$, $h_3 = 1.85$, $h_4 = 1.90$, $h_5 = 1.94$, $h_6 = 1.97$. The curves of frequency are drawn for only M, h_1 and h_6, and their standard deviations are $\sigma = 1.0000$, $\sigma_1 = 0.9055$, $\sigma_6 = 0.8944$. (Data from Pearson.)

Darwin regarded this point as of so great importance that he offered to give up his whole theory if it could be proved in a single case that a structure or instinct is developed in one species for the exclusive benefit of another. To be sure, there are innumerable cases in which the characters of one species are of use at another, but this value to the other species is purely secondary. For example, the nectar of flowers forms the daily food of bees, but this nectar is primarily of use to the plant in securing the visits of the bees, and thus providing a means for the transportation of the pollen and cross fertilization. As the result of thoughtful search Romanes was able to discover only two cases that appear to be exceptions to this rule. It is well known that the aphides (green plant lice) secrete a sweet juice that is much sought after by ants. So far as we know, this secretion is of no value to the aphid. But it has not yet been investigated sufficiently to show that it is of no use. It may be a means of removing waste products of metabolism. Moreover, it seems to be rather more of a luxury than a necessity for the ants. The other case is still more remarkable. It is the production of galls upon plants as the result of the growth of an insect larva within the tissues of the plant. The gall forms a perfect home for the larva, and differs in character, not only in different plants, but it differs also according as it is produced by one species of insect or by another, each species of insect having its own peculiar form of gall. All grades are found, from simple cysts, hardly worthy to be called galls, to struc-

tures which are extremely elaborate. Here we have a structure developed by a plant apparently for the benefit of an insect. But, as pointed out by Romanes, the gall arises as a reaction on the part of the plant to a poison produced by the insect, and its first appearance was probably due to one of those accidental effects of an injurious substance upon an organism, such as Herbst discovered when he treated sea-urchin larvæ with potassium and lithium salts. The gall-forming property, being of use to the insect, would be preserved and modified by natural selection acting directly upon the insect, and the plant would be affected indirectly.

The third line of evidence is that which first attracted Darwin's attention to the principle of selection. Darwin found that in the production of domestic varieties of animals and plants artificial selection is the keynote to success. All of our domestic productions are descendants from wild species, but in many cases either the wild parent species has been exterminated, or else the domesticated descendants have been so greatly modified that it is impossible to recognize the ancestral form. The differences between artificial varieties and between them and the original form, when known, are often as great as the differences between species, or even between genera, of animals and plants in the natural state. Compare a deer hound with a King Charles spaniel, a Cochin China with a game cock, a pouter pigeon, a fan-tail, and the wild rock dove, from which Darwin showed the pigeons to be descended. Romanes calls special attention to the well-marked varieties of canary birds, and regards this as a case of unusual interest because of the shortness of time during which the evolution has taken place, the first mention of these birds that he could find being by Gesau in the sixteenth century. Among most of our domestic animals man has been selecting more or less unconsciously the individuals which best served his needs or answered to his ideal of beauty; and this has been going on since prehistoric times. In later years selection has been practised with great care and with reference to more exact ideals, and the progress made is truly wonderful.

Darwin regarded evolution as an extremely slow process, and this idea prevailed for a long time, but recently several cases of very marked change in domestic forms have come to light where the change has been comparatively rapid. The American trotting horse is a case in point. An ordinary horse runs when he wants to move rapidly, but the trotting horse prefers the trot, and will keep to that gait until he attains a speed far beyond that at which other horses would be forced to break into a gallop. The lowest limit of what is regarded as racing speed in a trotting horse is a mile in two minutes and thirty seconds. The first horse to make a mile within 2:30 was Lady Suffolk, a great-granddaughter (by three crosses) of Messenger, a thoroughbred race horse imported from England in 1788, and famous as the ancestor of almost all American trotting horses. Lady Suffolk was foaled in 1833, and made her record in 1845. Form that time the speed of the fastest trotter has steadily increased, until Uhlan in 1913, made the remarkable record of 1:54½, beating the record made by Lou Dillon ten years before. But the improvement of the trotting horse is seen best when we compare the number of fast trotters at a recent date with the number several years before. In 1892 there were 116 horses with records of 2:15 or better, at the end of 1897 there were 585 horses with such records, and during 1897 190 horses entered this class, only 7 less than the total number in 1892, and many of these had no previous record.

Now is this improvement due to the selection of fortuitous congenital variations, or to some other cause? If races are changed by the inheritance of acquired characters, this process should be expected to be efficient in the case of the trotting horse. This question will be discussed later when we consider the inheritance of acquired characters. [illegible] But it may be said now that [illegible] trotters from Lady Suffolk to Cresceus (2 [illegible]), Cresceus is the only one having a sire with a record below 2:30, and The Abbot is the only one [illegible] with any record at all, and [illegible] careful study of the pedigrees of trotting horses will fail to show that horses which have been trained have any greater power of transmitting trotting speed than horses which have not been trained. It is probable that such a study will show that that combination of instinct and structure which enables a horse to trot at a high speed has arisen as a fortuitous variation in a few individuals, and that fortunate selection and crossing of their descendants during eight or ten generations at most has produced the remarkable result that we see to-day. This is the more probable since Galton has shown that variations in speed follow the normal curve. Take the pedigree of Alix, for example. Both parents of this champion trotter were totally untrained. Her paternal grandsire has a record of 2:21¾, the others have no record. Of her grandparents only one has a record (2:21½), and of her great-grandparents again only one has a record (2:42). On the other hand, her descent is traced by more than fourteen converging lines from Messenger, the ancestor of Lady Suffolk. She is descended by four lines from imported Bellfounder, the son of a Norfolk trotter, and by four lines from Amazonia, a "natural trotter." Moreover, she counts among her ancestors the sires of three champion trotters: Dexter, 2:17¼; Goldsmith Maid, 2:14, and Maud S., 2:08¾, and if each ancestor be regarded as a separate individual at each place in which he occurs in her pedigree, it will be found that she is descended from seven sires of champions, three on the paternal side, and four on the maternal side.

But if the inheritance of acquired characters may be a factor in the development of the trotting horse, there are other cases of rapid improvement in which it cannot have entered. One of these, the cultivated cyclamen (*Cyclamen latifolium* Sibth.), is one of the spring wild flowers in Greece and Syria. It has pink flowers with a ring of darker color at the throat (W. T. T. Dyer, *Nature*, May 20, 1897, vol. lvi., pp. 65–68). The species is said to have been first cultivated in Europe at Lille in 1731. It was probably obtained from Syria. "The Lille plant ultimately went to Ghent, and it has been asserted that all the cultivated forms in existence are descendants from this one individual." A variety with white flowers—"pure white with a bright purple button"—was described in 1768. The modern development of the plant began in 1860, and started with one of the principal growers (Messrs. Sutton) with the old "crimson and white."

The changes have been brought about entirely without resort to hybridization. But starting with the slightest deviation, even so small as the slighest difference in a cotyledon of a germinating seed, by careful self-fertilization and selection the present varieties have been produced. The changes produced have been in the size of the flower, its fragrance, color, and form of corolla. The original form has narrow, twisted, reflexed petals about an inch long. The cultivated varieties have broader, less twisted petals, and in one variety they have reached a length of three inches. This was accomplished by continuous inbreeding and selection. The old crimson and white had a crimson ring at the throat, but was otherwise an albino. From this, forms have been produced varying from pure white on the one hand to a uniform deep crimson on the other. "The modern colored forms were obtained in the first instance by selecting forms in which the colored ring showed a disposition to spread into the white corolla segments. The first indication would be a streak [illegible] selection from self-fertilized plants the streak was widened into a stripe. Continuing the process, the stripes united, and a [illegible]

obtained." The colored varieties when self-fertilized come true from seed.

One of the most remarkable modifications in the form of the corolla is the spreading of the segments. Cyclamen belongs to the order *Primulaceæ*, and is distinguished from the rest of the tribe *Lysimachiæ*, to which it belongs, by the reflexed segments of the corolla. In the variety with a spreading corolla, then, we see a modification of a character which not only distinguishes the species but also the genus.

Doubling has occurred in one variety. Ordinarily doubling is due to a homeotic variation of the stamens by which they become petal-like. In this case, on the other hand, the stamens retain their proper structure, and both they and the segments of the corolla become increased in number.

The butterfly form is a case of parallel variation, it having been obtained independently by several horticulturists. In this variety the petals are partly spreading and arched, and are toothed and curled at the edges. It is interesting to note that in one case at least there is a correlation between the corolla and the leaves, for they also are toothed. This variety arose as a well-marked sport which was improved by selection.

Another example of the rapid effect of selection is the tomato. The different varieties of the edible tomato (*Lycopersicum esculentum*) differ as much, if not more, than do the other species of the genus (Bailey, "Survival of the Unlike," pp. 112–125). The Trophy tomato was the result of crossing and selection begun by Dr. Hand, of Baltimore County, Md., in 1850. He began by crossing the smooth "Love Apple," which was filled with juice and seeds, with the common convoluted red tomato of that period, which was so rough as to be unfit for use. After several years by continued in-breeding and selection he succeeded in producing a form which combined with the smooth skin of the Love Apple the solid fleshly mass of the compound red. This accomplished, he continued to select a very few specimens of the best and best flavored of the earliest fruit for the next year's seed, and thus increased the size and solidity of the fruit, until in 1870 he had produced a variety which was a mass of flesh interspersed with ten or more small seed cells, and which was the earliest, largest, smoothest, the most fleshy, and much the best flavored of all the kinds then grown. Moreover, the continued selection had resulted in a marked fixity of type, which was very different from the two- or three-celled original form.

The growth of sea-island cotton, on the islands off the coast of South Carolina and Georgia, was made possible only by the process of selection. When first introduced from the West Indies, the plants were not adapted to the climate, and seldom produced fruit. But by rigorous selection a race was produced which was well adapted to the climate, and the quality of the fiber was improved until now it is the best grown in any part of the world. That the improvement in the fiber is due to selection and not to conditions of growth is shown by the fact that when selection is relaxed the fiber deteriorates (Webber, "Year-Book Dept. Agric.," 1898, p. 358).

Many more examples might be cited to show how great the changes are that have been produced by artificial selection. Many domestic races produced in this way differ as much from each other and from the parent species as do species or even genera in nature. If artificial selection acting during only a few generations can produce so great changes, how much more effective must have been natural selection, which is probably much more rigorous and continuous, acting through countless ages.

De Vries (1905) recognizes a broad analogy between artificial and natural selection. But he maintains that the selection of normal individual variations can lead only to improvements of the race of a more or less temporary character, and that the evolution of new races can be accomplished only by the selection of mutations. In confirmation of this view, it will be noticed that in the cases cited above most of the improved races have been started by the selection of some abnormality, although it may have been a slight one. Bateson (1913), however, is not convinced of the importance of mutations, that is groups of new characters, in evolution; but is inclined to attribute more importance to the appearance of new single characters, whether substantive or meristic.

To sum up, then, we have considered three lines of evidence that natural selection is a factor in organic evolution: 1. We have observed facts of the struggle for existence and a selective death rate. 2. We find that no organism in nature has developed any structure or function for the exclusive benefit of another species—contrary to what we might expect to find on the theory of special creation, but just what must be the case on the theory of natural selection. (This would probably be true also on any theory of evolution). 3. We find that the analogous process of artificial selection has been the most effective means of developing in domestic races those qualities of most value to man, and therefore we infer that natural selection has been an important factor in developing in natural species those qualities of benefit to themselves.

One of the best ways of testing a theory is to attempt to apply it to concrete cases of the class of phenomena which it is supposed to explain. In the applications of the theory of natural selection we shall find the fourth and last line of evidence in favor of the theory.

The phenomena in question are in general those of *adaptation*. Many plants have especial floral structures which facilitate cross fertilization by the aid of insects, and Darwin has shown that this is of great advantage to the species. Climbing plants have peculiar structures and powers of movement that are clearly of advantage in enabling the long, slender stems to find support. Both plants and animals frequently have structures which serve to repel enemies, and many animals are provided with a protective coloring which renders them inconspicuous to their enemies or to their prey. Other animals, provided with offensive secretions or weapons, also have conspicuous warning colors which render them less liable to attack. Finally, there are inoffensive animals which resemble the offensive ones superficially in color and form, and by this mimicry probably share in their immunity from enemies.

These are examples of a large and important class of phenomena that, rejecting the theory of special creation, can be explained by only one theory of evolution, that is the theory of natural selection. Thus we see that natural selection is not merely a factor, but is perhaps the most important of all factors in organic evolution.

Passing over the *objections* to the theory of natural selection that arise from misunderstanding of the theory or ignorance of the facts, there are four objections that are important.

First is the objection that selection is merely a process of elimination and can produce nothing. It is of course true that without variation there can be no selection; but may not selection by determining the parents of one generation influence the course of variation in the next, and thus indirectly lead to the production of new characters? That the effect of selection upon hereditable variations is only apparent, not real, seemed to have been proved by Johannsen and by Jennings in their experiments upon "pure lines," that is upon the descendants of one homozygous parent. On the other hand, the equally careful experiments of Castle upon polydactylous guinea-pigs, of Woltereck upon Daphnia, and especially of Castle and Phillips (1914) upon the color-pattern of hooded rats, show that new types may be established by selection of variations within pure lines.

Second, natural selection cannot be the cause of "the origin of species," because most closely related species are distinguished by differences of form or color that are so minute that it seems impossible for them to be of selective value. Not knowing all the conditions of life, we are unable to say that such differences are not in themselves of selective value or correlated with characters of selective value. But in many cases there is no evidence of such value or correlation.

Sinnott (1913) has made the interesting suggestion that it is just because these trivial characters have no selective value that they have become sufficiently fixed to furnish the "taxonomic type." He regards natural selection as having for its chief function the prevention of too great fixity in characters having a survival value, and thus to promote that adaptability to varying conditions that is as important in nature as in human life.

Third, the one characteristic that surely distinguishes species from varieties is the infertility of species when crossed with other forms. Now it is difficult to see how infertility of any form could be produced by natural selection, except in relation to the food supply. But food supply could have nothing to do with infertility between species.

This form of sterility has never been produced experimentally, and we can only suppose that it has arisen in connection with the appearance of other new characters.

Fourth, a distinction must be drawn between linear evolution and divergent evolution. Linear evolution would be the gradual change of specific type by which the new species would become different from the old, but the number of species would remain the same. Divergent evolution, on the other hand, would mean the splitting of original specific types into two or more new types. Now it would be impossible for a species to become multimodal and ultimately to separate into two or more by the action of natural selection alone.

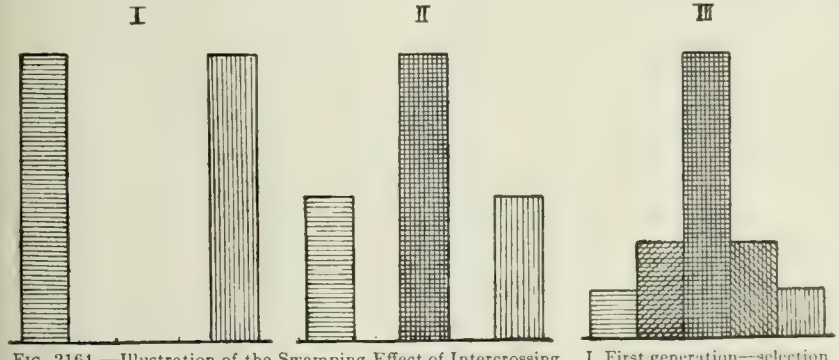


FIG. 2164.—Illustration of the Swamping Effect of Intercrossing. I, First generation—selection intense, model type destroyed leaving two pure types distinctly differentiated; II, Second generation—random mating of the two pure types, of equal fertility. Results, mixed type twice as numerous as either pure type. III, Third generation—random mating of the second; all individuals equally fertile. Results, mixed type six times as numerous, and intermediate forms four times as numerous, as either pure type. (Data from Pearson.)

For there would be nothing to prevent individuals of different types from breeding together and thus reducing them all to a common type.

These objections are valid, unless some other factor may be brought to the aid of natural selection. But selection is not the only means employed by the breeder of domestic races; then why should natural selection be supposed to be the sole factor of organic evolution?

Isolation.—When a breeder wishes to improve a race or to create a new one, he not only makes a very careful selection of his breeding stock, but he builds a fence around it and guards it against admixture with other stock. That this principle of isolation, or segregation, is of great importance as a factor of organic evolution has been pointed out, especially by Wagner, Gulick, and Romanes. By isolation [illegible] prevention of intercrossing between a separated [illegible] tion of a species or kind and the [illegible] kind." Romanes regards [illegible] factor of vast importance in [illegible] it to be less fundamental and of more [illegible] tion than the principle of isolation. He [illegible] only in its importance by the two [illegible] of heredity and variation, this principle of isolation constitutes the third pillar of a tripod upon which is reared the whole superstructure of organic evolution."

From this point of view natural selection becomes a special case of isolation, where the individuals best fitted for their environment are isolated and prevented from crossing with inferior individuals by the death of the latter. But, as we have seen, this form of isolation can produce only linear, or monotypic, evolution, for of the two separated sections of the species only one survives. It is possible, however, that the modal type might become the least favorable, and that selection would result in the separation of two types equally fit. To borrow an illustration from Pearson, suppose a short femur and a long radius to be equally favorable and their combination in one individual so rare as to be negligible. Rigorous selection would produce two pure types, as in Fig. 2164, I. But natural selection alone is powerless to prevent the free intercrossing of these types, and the birth curve of the next generation will have the form of II in Fig. 2164, if we assume that this is a case of blended inheritance, or that we are dealing with characters compounded of many Mendelian factors, which would amount to the same thing. Selection will need to be repeated with equal rigor, otherwise in the third generation we shall find an approach to the normal curve with the mixed type as the mode, six times as numerous as either pure type (Fig. 2164, III). By natural selection alone, then, we should have in such a case merely periodic selection and no progress in divergent evolution. In order that the types A and B may become the foundation for two new species, some other barrier must arise between them. We must look for some other form of isolation.

Isolation may be total or it may be partial of various degrees. A more important distinction is between isolation that is "discriminate" and that which is "indiscriminate." Indiscriminate isolation allows free intercrossing of all variations, or *apogamy;* while discriminate isolation allows only individuals having some point of resemblance to breed together, or *homogamy.*

Apogamy will occur only where sections of the species contain large numbers of individuals at the time of separation. In this case there will be no change of type unless the separated sections become subjected to different conditions so that natural selection may act in a different manner.

Where the isolated section is so small as not to be a fair sample of the population, there will be a sudden change of type. That is, the mean of this section will differ somewhat from the mean of the species as a whole, and there will be a certain degree of homogamy. But this change of type may be very small, and it is very doubtful if homogamy without natural selection can produce any continuous change of type, although Gulick and Romanes have held that it can.

Geographical isolation has, without doubt, played a very important part in the differentiation of species.

As we have seen, it will give rise to homogamy or apogamy, according to the number of individuals separated. But probably its most important effect has been to allow the gradual adaptation of parts of a species to different conditions, which would be impossible where free intercrossing could take place. This would account for the facts expressed in Jordan's law of geographical distribution, which has been stated as follows: "Given any species (or kind) in any region, the nearest related species (or kind) is not to be found in the same region, nor in a remote region, but in a neighboring district separated from the first by a barrier of some sort, or at least by a belt of country, the breadth of which gives the effects of a barrier." According to Jordan (1909) this holds as a general rule for most animals and plants. Such closely related species he calls "germinate species," and says that wherever a distinct barrier exists germinate species may be found on the two sides of it. If the barrier is imperfect there may be a mingling and intergradation of forms. But "a subspecies that lives permanently in the same region coincident in range with the species from which it springs is unknown in zoology."

There are numerous forms of homogamy. "When, for example, any section of a species adopts somewhat different habits of life, or occupies a somewhat different station in the economy of nature, homogamy arises in that section." In plants differences in times of flowering, in habitat, or in the habits of insect visitors may give rise to homogamy. But, according to Romanes, aside from natural selection, the most important form of homogamy is sexual incompatibility, which he calls physiological isolation. In this form of isolation individuals having some peculiarity of the reproductive organs are prevented by this from crossing with individuals having some other peculiarity. If this sterility between different sections of the species be correlated with other peculiarities, we have what Romanes calls *physiological selection* and the formation of a new race, which is free to develop independently of the rest of the species.

This theory is based upon two principal considerations: (1) the general variability of organisms, including the reproductive organs, and (2) the fact that the character that chiefly distinguishes species from varieties is sterility between them. This sterility may be absolute, or it may result in the production of more or less sterile hybrids. Whether sterility has arisen before or after other divergent characters, it will be, in either event, an important factor in evolution. We need not now suppose it to have arisen gradually; but it may have arisen in a mutation and be correlated with some Mendelian factor. If this were dominant the offspring of the first cross would be entirely sterile with the parent species, but, if fertile *inter se*, would produce in subsequent generations a diminishing number of individuals capable of crossing. If the critical factor were recessive one quarter of the F_2 generation would be sterile with the parent species, and to this isolated group some additions would be made by subsequent generations.

The chief evidence for the theory of Physiological Selection is found in the topographical distribution of plants. Naegeli found ninety-five per cent. of allied species and a great number of allied varieties living together in the same stations separated by no barrier except sterility. And this is confirmed by the experiments of Alexis Jordan, published in 1873. He discovered in plants great numbers of varieties hitherto overlooked because of the minuteness of the differences between them. And he found that in many hundreds of cases these varieties in nature living side by side, would breed true to seed and be sterile *inter se*.

Sexual Selection.—Another series of special cases of isolation is furnished by the various kinds of sexual selection. This term, as recently employed by Pearson, includes all forms of *selective mating*. This is sharply contrasted with *pangamic mating*, or the mating at random of all members of the race. The forms of selective mating are classified by Pearson as follows:

1. Autogamic mating, or self-fertilization, including the fertilization of a flower by another flower on the same plant.

2. Endogamic mating, or mating within the family, brood, or clan, a very effective mode of isolation.

3. Homogamic, or assortive mating, the union of like with like, the two mates not necessarily being of the same brood.

4. Apolegamic (from ἀπολέγω, I pick out, refuse), or preferential mating. This is *sexual selection* in the sense in which the word was originally used by Darwin.

5. Heterogamic mating, or the union of unlikes. Darwin found many cases of this form of mating in his study of the effects of cross and self-fertilization in plants. It includes those cases in which the species is polymorphic and a union of diverse forms is prepotent over a union of similar individuals.

The theory of sexual selection in the narrower sense was devised by Darwin to account for the origin of certain secondary sexual characters in animals.

There are many species in which the individuals of one sex, usually the male, fight with one another for the possession of mates. The fur seal is an excellent example. In such cases it is obvious that those males having superior weapons and strength to use them will beget the greater number of offspring, and that these will inherit and transmit their favorable peculiarities. This might be regarded as a special form of natural selection.

But there are many species, especially among the birds, in which the contest for mates is carried on by gentler means. In these cases the males usually seem to vie with one another in an attempt to excite the sexual instincts of the females by melodious song and cries, by movements of the body, or display of bright colors. It is supposed that those males which are most attractive to the females will produce the most offspring, and thus the development of ornamental secondary sexual characters is regarded as due to selective action on the part of the females.

Of course, this theory can apply only to animals of a relatively high grade of organization, and the efficiency of this factor in evolution has been denied entirely by Wallace and others.

To enter into this controversy would require too much space. But it may be pointed out here that (1) males are frequently distinguished, not only by bright colors, but by a highly decorative color pattern, sometimes associated with a highly elaborate structure, as in the peacock, angus pheasant, bird of paradise, etc.; (2) many birds possess not only call notes, but a melodious song, often, to our ears at least, of great beauty, as the wood thrush, the wren, and the catbird; (3) and, finally, the deer family possess handsome arborescent antlers that are highly ornamental, but certainly less efficient weapons than the straight horns of the antelopes. Now these facts cannot be explained by the assumption of vigor of the male, nor by the usual process of natural selection, while they may be explained on the theory of preferential mating. On the other hand it should be noted that (1) bright colors and decorative pattern may occur in both sexes, (2) that there is little or no evidence that the females exercise any choice with regard to beauty of color or song, and (3) there is evidence in the insects at least that secondary sexual characters may arise as mutations and be inherited as Mendelian factors without any selection (T. H. Morgan, 1913).

The question as to whether the choice of the female is or is not an efficient factor in evolution cannot be determined by a few or many detached observations. If it be a factor, it will exhibit a general tendency in one direction, and to discover such a tendency it is necessary to resort to careful statistical inquiry.

Pearson has pointed out the method for making such inquiries, and in the case of man he found no evidence of preferential mating in respect to stature, but he found distinct evidence of preferential mating in the matter of eye color or of some closely allied character in the male. The general tendency is for the lighter-eyed to mate, while the dark-eyed are less frequently mated. He concludes that it cannot be doubted "that sexual selection in the form of preferential mating is not a mere hypothesis, but can be demonstrated to actually exist in the case of man."

Preferential mating would have an effect on evolution similar to that of natural selection. That is, there might be a tendency to progressive change of type, but it could not alone produce differentiation. On the other hand, it is clear that self-fertilization and endogamy would aid differentiation, and assortive mating would also have this effect, if mating of this kind takes place.

Pearson, using the method of correlation, studied the stature of 1,000 pairs of husbands and wives, and the eye color of 774 pairs. And he found that, "the assortive mating is indeed so great that husband and wife have for the average of these two characters a sensibly greater degree of resemblance than that assumed on theoretical grounds to hold for first cousins and approaching the degree of resemblance found for uncle and niece."

Panmixia.—The presence of vestigial organs in vast numbers of species, and the fact that some groups entirely lack organs possessed by other related and perhaps lower groups, as, for example, the snakes, lead to the belief that in the course of evolution organs in many cases have dwindled in successive generations, and sometimes entirely disappeared.

Perhaps the most natural explanation of these facts would be to ascribe them to the inherited effects of disuse. But this explanation is inadequate, for it will not account for the loss of parts in plants, nor for the loss of passively protective structures in animals; and it is particularly inapplicable to the cases of the loss of wings in neuter insects, for neuters produce no young, and hence there could be no inherited effect.

To meet this difficulty Weismann introduced the hypothesis of *panmixia.* This is merely random mating without selection. But, as has been pointed out by C. L. Morgan and Pearson, the only effect of panmixia would be a reduction from the survival mean to the birth mean. There would be a sudden slight change of adult type in one generation, and after that no further effect.

So it would seem that we must fall back upon Darwin's principle of natural selection and economy of growth. For example, in the case of wingless insects inhabiting small oceanic islands, it is evident that if the species were unable to become strong fliers, it were better for them not to fly at all. Because weak fliers would be apt to be blown out to sea and lost. Darwin argued also that useless organs require as much nourishment as useful ones, and in time of dearth the animal which had to find nutrition for the smallest amount of useless tissue would stand the best chance of surviving. This might account for the dwindling of useless organs, but it would not account for their complete disappearance. For it cannot be supposed that the presence or absence of a minute vestige of an organ could ever be a matter of life or death. And as no satisfactory hypothesis has been advanced to explain this, we shall have to regard it as one of the unsolved problems of evolution. It is possible, however, that the principles of Mendelian inheritance may help to solve this problem. The absence of a character is usually recessive, and if there should be a correlation with some useful character so that homozygous recessives would tend to breed together, the absent factor would soon be eliminated from the race.

Orthogenic Evolution.—Paleontologists have asserted that they find in the study of extinct animals evidence of a constitutional tendency [illegible] definite direction. Such [illegible] to something inherent in the constitution, without action of organic or [illegible] orthogenic, or *bathmic evolution.*

The evidence that such [illegible] not very convincing. Nevertheless, supposing it to be a fact, many explanations [illegible] account for it. Mivart suggested an innate tendency, and Naegeli, a perfecting principle. But these are merely words and explain nothing. This is the kind of evolution that is postulated in Bergson's philosophy, to which reference was made in the introductory paragraphs of this article. Hyatt from a study of certain fossil mollusca, ammonites, found evidence of a cycle of development of species corresponding to the cycle of individual development. He holds that there is a law of growth which compels species to pass through the stages of youth, maturity, and senescence. This may be true of the ammonites; it may be the reason that they are extinct. But it has not been shown to be a general law, and the law itself would need explanation. For Eimer (1889) the transmutation of forms is due to inheritance of acquired character and definite evolution, or orthogenesis, and the cause of the latter is "organic growth."

Weismann has offered as an explanation of bathmic evolution his hypothesis of *germinal selection.* But this is a pure assumption based upon Weismann's theory of the structure of the germ plasma, which is, however, in haromony in a general way with the data of Mendelian inheritance (see *Heredity*).

The first reasonable hint of a cause for bathmic evolution has been furnished by Pearson in his theory of *reproductive,* or *genetic, selection.* From the study of four thousand three hundred and ninety families in the middle and upper classes, Pearson found that variations in fertility do not follow a normal symmetrical curve, but have a very skew distribution, small families being much more numerous than large ones. The result is that twenty-five per cent. of the parents produce fifty per cent. of the children. It is clear that on the average one pair of the smaller group of more fertile parents will have as much effect on the type of the next generation as three pairs of the larger less fertile group. Therefore, if fertility be inherited, and if there be a correlation between fertility and any other character, progressive change of type may take place by a purely bathmic process, unless checked by natural selection or other cause. As to the inheritance of fertility, Pearson found from a comparison of the sizes of the families of a thousand pairs of mothers and daughters, where the marriages had lasted fifteen years or more, that there was very good evidence of such inheritance. (He obtained a coefficient of heredity of 0.215 with a probable error of ±0.020.) Similar results were obtained by the study of 1,000 pairs of paternal grandmothers and granddaughters. Here the coefficient of heredity (0.112 ± 0.021) is about half as large as for mother and daughter, as would be expected by the law of ancestral heredity, and this is an example of the transmission of a female character through the male line with undiminished intensity. Thoroughbred horses also furnished evidence that fecundity is inherited between dam and daughter and also through the male line, fecundity being transmitted by a sire from his dam to his daughter. There is also evidence of correlation between fertility and other characters. In man, Pearson found that the more fertile women are slightly taller than the less fertile, and dark-eyed fathers and mothers are found to be more fertile than those with light eyes. Every farmer knows that breeds of fowls differ in capacity to produce eggs, and Pearl (1912) has made the interesting discovery that a high grade Barred Plymouth Rock hen can transmit her superior fertility only through her sons to their daughters.

Poppies have radiating ridges on the upper part of the seed capsule, the stigmatic bands. In 4,443 capsules of Shirley poppies the range of variation was from 5 to 19 bands and the modal number was 13. Capsules with 12 to 13 bands were found to be very full of seed, while there were hardly any in capsules having very few or very many bands. Likewise in 3,212 seed capsules of *Nigella hispanica* the range of variation in the number of segments was from 2 to 20, with 8 for the modal number. Capsules with 8 segments were found to be very fertile, while those with 10, 11, and 12 segments contained hardly any seed, and those with 5 or less were practically sterile.

It is evident, then, that where the most fertile character coincides with the modal character, as in the case of the poppies and Nigella, this differential fertility, or genetic selection, will tend to preserve the stability of the race, and in order that differentiation of type may take place, this effect will have to be overcome. On the other hand, if the most fertile character differs from the modal character, as appears to be the case in the eye color of man, then there will be a progressive change, unless this is checked by preferential mating, natural selection, or some other cause. So differential fertility is to be reckoned with as a factor in evolution. It is certainly in some cases a conservative factor, and it is possible that it may become a cause of progressive change of type. But whether bathmic evolution has ever taken place by this means without the aid of other factors is another of the unsolved problems.

Inheritance of Acquired Characters.—An "acquired" character is one which arises during the life of the individual as the result of functional activity or in response to an external stimulus. The term is an unfortunate one, for to many minds the word "acquired" conveys simply the impression of newness without regard to the source of the change. To meet this difficulty C. L. Morgan has proposed to use the term *modification* in place of acquired character, and to reserve the term *variation* for changes of purely congenital origin. Moreover, it is often difficult to distinguish between modifications and variations. For example, deafness may be due to congenital malformation of the ear, or it may be due to disease. In the first case it would be a variation, in the second it would be a modification. Now Fay in his study of the inheritance of deafness often found it difficult to decide in which class a given case should be placed.

The factors of organic evolution that we have examined so far have been the great factor, natural selection, and a number of others more or less aiding and accessory to it. We have seen that natural selection is itself conditioned by three other factors: (1) variation, (2) inheritance, and (3) the struggle for existence.

Natural selection is only indirectly concerned with the origin of variations. So long as variations are of the right kind and are capable of being transmitted, natural selection, with the aid of isolation, will protect and develop them. It is evident, then, that if the purposeful, adaptive modifications of the individual that arise as the result of its reactions to the stimulus of its environment may become hereditary, they will be a great aid to natural selection. For they will insure the presence of the right kind of variation to be selected when it is needed. Darwin thought that such acquired characters are inherited, and he regarded them as an important aid to natural selection. The neo-Lamarckians, on the other hand, have taken the view that the inheritance of acquired characters is much more than an aid to natural selection; that it is itself a prime factor of organic evolution.

Now comes the school of Wallace and Weissmann, and says that the inheritance of acquired characters not only is not a prime factor in evolution, but it is not even an aid, as Darwin supposed, to natural selection. In fact, according to this school, acquired characters are not in any degree inherited. The question then is, Are acquired characters inherited, and if so, how far has this inheritance been a factor in the origin of species?

To discuss fully the subject of the inheritance of acquired characters as a factor of organic evolution would require much more space than we have at our command. But we may endeavor to present a few of the thoughts which seem to be of greatest importance in this connection.

In the first place the neo-Lamarckian contention that the inheritance of acquired characters is the *prime factor* in evolution can be ruled out of court at once as manifestly untenable. There are a large number of structures in both plants and animals that can have developed only as the result of continued selection. Such are the cases of mimicry, both in form and color, warning colors, adaptations for cross fertilization in plants, and the like. But the most instructive examples, as pointed out by Brooks, are to be found in species having normally sterile individuals. In many species of polyps there are nutritive, offensive, or protective persons in each colony which never produce offspring; and among ants, bees, and termites, the most numerous and most active members of the community are sterile workers. These sterile individuals generally differ from the fertile males and females, presenting very beautiful modifications of both structures and instincts in adaptation to their very different functions and mode of life. Now as the worker has no offspring its acquired character cannot be inherited. The evolution of the worker must be explained as the result of natural selection, preserving those queens that produced the workers best adapted to the needs of the species.

If such complex adaptations as the mechanism for cross fertilization in orchids, and modifications observed in the worker of the honey-bee have arisen without the aid of the inheritance of modifications, a strong presumption is raised in favor of the view that natural selection and not inheritance of acquired characters, has been the prime factor in evolution generally. This being granted, should we not return to the position taken by Darwin, that while natural selection is by far the most important factor in evolution, it has been aided by the favorable variations resulting from the inheritance of acquired adaptive modifications?

The amount and kind of evidence that is required to prove any generalization depend upon its theoretical probability. Now if we accept Darwin's view as to the inheritance of acquired characters, we must also accept his theory of heredity or some theory closely allied to it. The study of heredity, however, makes it clear that the only theory that corresponds with what is known of the origin of the germ cells and the subsequent development of the embryo utterly fails to explain the inheritance of acquired characters. The theory of the inheritance of modifications involves the necessity of some mechanism by which the presence of a somatic character in a parent will so affect the germ-cells that this character will reappear in the offspring. No such mechanism has been discovered; and the rapid increase of knowledge concerning both the physical basis and the visible results of heredity that has followed the rediscovery of Mendelian principles, has only served to strengthen the theory of the continuity of the germ plasm. This makes the inheritance of acquired characters seem theoretically improbable, and necessitates a critical examination of the testimony in its favor. This evidence may be classified as follows:

1. Indirect evidence.

(*a*) Analogy between congenital and acquired characters.

(*b*) Apparent uselessness of nascent structures observed in fossils.

(*c*) Reflex actions.

(*d*) Instinct.

2. Direct evidence.

Reported cases of inherited effects of (*a*) use or disuse, of (*b*) climate, and of (*c*) food.

3. Experimental evidence.

(*a*) Brown-Séquard's experiments on guinea-pigs.

(*b*) Experiments of Hoffman, Carrière, and Buckman on plants.

It will be most convenient to take up this evidence in the reverse order. Beginning with the experimental evidence, Brown-Séquard's experiments were supposed to show that epilepsy induced in guinea-pigs by operation is inherited by their offspring. But Romanes repeated these experiments as carefully as possible, and his results were inconclusive. More recently T. H. Morgan (1903) has suggested other explanations for the facts, such as they are.

Carrière and Buckman were able to produce change in plants increasing in successive generations, by growing them on different soils. But here the principle of selection was employed, and it is impossible to say how far the result is due to selection and how far to the inheritance of acquired characters. It is also to be remembered that food is one of the factors in the environment that may affect the germ plasm directly. It is possible, therefore, that the changes observed in the succeeding generations of plants may be due to the new constituents of the sap affecting the germ plasm directly. The new characters would not then be acquired characters in the technical sense, but true congenital variations. Moreover, these experiments are offset by a number of experiments made by careful observers especially to test the question of inheritance of acquired characters, which have given purely negative results.

Fay found that when both parents are congenitally deaf, twenty-six per cent. of the children are deaf. When one parent is congenitally deaf and one has acquired deafness, the percentage of deaf children is 6.5 per cent., while where both parents have acquired deafness it is only 2.3 per cent., and this last percentage may be due to an error in determining whether the deafness is congenital or acquired.

An especially careful series of experiments is described by Sumner (1910), who found that white mice when kept in a warm room during growth have longer tails, feet, and ears, than mice that have been kept in a cold room during the corresponding period. After pairing, the females of both lots when found to be pregnant were removed to a common room. The offspring, 286 in number, were measured when six weeks old, and for each of the three measurements there was a small average difference in favor of the warm room descendants. But these differences are so small and so little in excess of their probable errors, that alone they are not convincing.

In a series of experiments upon a rotifer, Hydatina, Whitney (1912) has endeavored to ascertain if the effects of alcohol are inherited. His observations extending through twenty-eight generations showed that in these animals the effect of alcohol was partly eliminated in the first generation and totally disappeared by the end of the second generation after the alcohol was removed.

For a review and criticism of other experiments on the inheritance of modifications, especially the remarkable experiments by Kammerer, the reader should consult Bateson (1913) pp. 187–212.

So the experimental evidence, which should be expected to give the most conclusive answer, is after all unsatisfactory.

The direct evidence as a whole is worthless. Most of the cases have been reported by unscientific persons unskilled in exact observation. The cases in which there have been competent observers can be explained as well either as the result of selection of congenital variations or as the result of the direct effect of environment upon the germ plasm.

It is the indirect evidence that offers by far the best cases in favor of the [illegible] characters. In the first place, that the effects of use and disuse of parts and the effects of external conditions, climate, food, etc. [illegible] a matter of common belief. We know the effects of these causes upon the individual, and we know that very minute individual peculiarities frequently are inherited. It is reasonable to suppose that these peculiarities caused by external conditions are inherited with the rest. No one can [illegible], that this line of evicende offers more than a presumption in favor of the inheritance of acquired characters. A better line of indirect evidence is furnished by those adaptations which apparently could not have been of use in the early stages of their evolution, and many paleontologists believe that they find in extinct species such nascent structures and that these prove the inheritance of acquired characters to be the prime factor in evolution. This is regarded as especially true of those cases in which a high degree of co-adaptation is required. Spencer, for example, presents the case of the giraffe as a form undoubtedly due to the inherited effects of functional activity. For as he rightly says, in order that the giraffe may carry his long neck, the forelegs must be lengthened, and the hind legs shortened. In fact, the whole shape of the body has to be altered, involving changes in a great many tissues and organs. If a breeder is trying to produce a variety having a new combination of characters, he selects individuals, some having one character, some another, and still others a third, and so on; and by causing these to breed together finally obtains individuals in which these characters are all combined. The Boston terrier and the Plymouth Rock fowl are excellent examples of such a blending of characters by artificial selection.

Now Spencer argues that it is impossible for co-adaptation to be produced by an analogous process in nature, for it is inconceivable in the case of the giraffe, for example, that any one of its peculiarities occurring alone in an individual could be of sufficient value to lead to the preservation of the animal by natural selection. In fact, some peculiarities without the others, for instance, the long heavy neck without unusually strong shoulders to support it, might be so great a disadvantage as to lead to speedy elimination. In order that the giraffe should be produced by natural selection, according to Spencer, it would be necessary for all of the coordinated adaptations to appear at the same time and in a large number of individuals. For, in the first place, these variations could be of no value unless all were present and coordinated; and in the second place, unless they occurred at the same time in a large number of individuals, they would be lost by the swamping effect of intercrossing. Moreover, they must continue to vary in the right direction in a large number of individuals. All of this Spencer holds to be impossible without the aid of the inheritance of acquired characters. Wallace (1889) has answered this argument by pointing out that what Spencer regards as impossible in nature, has repeatedly occurred among domestic races, and, as T. H. Morgan (1903) remarks, "The ancon ram and the turn-spit dog were marked departures from the normal types, and yet their parts were sufficiently coordinated for them to carry out the usual modes of progression."

Another answer to Spencer has been given by C. L. Morgan and others in the principle called *Organic Selection*. This principle includes two [illegible] the general capacity of organism to produce modifications of an adaptive character in response to functional activity or external stimuli, as in the strengthening of the muscles by exercise; and (2) the occurrence of congenital variations in the same direction, which give their fortunate possessors the advantage of a greater initial adaptability. A man with congenitally strong muscles has an advantage over one that has to acquire strength by exercise. If coadaptation has

arisen, as Spencer supposes, by the accumulation in one organism of a number of independently inheritable factors, and if *fortuitous, congenital variations and modifications due to functional activity may be of the same character and may occur side by side*, the latter supplying any deficiencies in the former, there is no longer any difficulty in the theory that even so complicated a coadaptation as is presented by the giraffe may arise by blending of minor congenital adaptations and therefore may be explained by natural selection. Moreover, it is to be borne in mind that it is a fallacy to speak of any one character as being selected. It is not a single character that is even preserved by natural selection, but it is the individual as a whole that is selected. While a favorable character may not of itself be of selective value, it may be perpetuated because it occurs combined with other favorable characters *either congenital or acquired*, all so blended as to give their possessor superior advantages.

Individually acquired modifications may, therefore, become important factors in evolution, not because they are inherited, but because by their acquirement the individual is able to supplement the deficiencies in its congenital characters. And when thus supplemented by individually acquired adaptive modifications, the inheritable congenital characters may be preserved by natural selection and continued from generation to generation, until by the operation of fortuitous variation and natural selection the acquired modifications are replaced by congenital characters of the same kind. So we may have two forms of coadaptation; first, coadaptation of mingled congenital and acquired characters, which precedes and prepares the way for the second, coadaptation of purely congenital characters.

The question whether coadaptation by the blending of favorable congenital variations really occurs in nature is answered best, according to Romanes, by a study of reflex actions and of instincts. Turning now to the evidence from reflex actions, it seems to us that Romanes has been unfortunate in selecting this line of evidence upon which to pin his faith in the *occasional* inheritance of acquired characters. He asks what use an animal can have for lower reflex centers when the higher brain centers are capable of originating the same nervous impulses. Now no one who has ever learned to dance, to swim, or to ride a bicycle will fail to appreciate the superiority of reflex over conscious action. No one can become an expert swimmer or rider until the movement is of the nature of a reflex, although the higher centers, the rational processes, may still be indispensable in case of accident. Romanes argues at length in regard to the apparent uselessness of many reflexes, together with the completeness of the mechanism required, and the consequent difficulty of explaining them by natural selection, and then proceeds to show that "if function produces structure in the race as it does in the individual," all is easily explained.

Now, in the first place, does function produce structure in the individual? Function may be said to produce size, strength, hardness, flexibility, and the like, but no case is on record where new muscles, new nerves, or any other new structure has been produced by any amount of functioning. Moreover, how can a structure be the result of a function when the function arises from the activities of the structure in question? A given intelligent act cannot take place until the whole neuro-muscular mechanism concerned in that act is complete, any more than if it were a reflex; and it is not evident how one can be explained by gradual development any better than the other. (It is like saying that a man can make a bicycle by riding it.) But even if we allow that a reflex mechanism may be the inherited result of intelligent action, this action must have been of a great deal of use to have been repeated often enough to make so great an impression on the organism. And, if it has been of so great use, it may well have had a selective value, and its development may then be explained by variation and natural selection.

It would seem, therefore, that reflex mechanisms and actions may be explained best by the principles of change of function and natural selection. When you learn to ride a bicycle, or better, when you learn to swim, you develop a new set of reflexes, but no new sense organs, nerves, or muscles, only the old ones in new combinations. Now the study of the morphology of the nervous system in any great group of the animal kingdom shows that a change of function in different parts of the nervous system is just what has taken place as we go higher in the scale of organization; and it is easy to see how any variation toward more intimate union of parts habitually used together would be preserved by natural selection until their interaction would be so easy as to become reflex.

Turning to instinct—if we regard it as "hereditary habit," that is if we suppose it to contain an element of transmitted experience, all is easily explained. The simple instincts are easily explained by natural selection, "but in all cases where instincts become complex and refined, we seem almost compelled," according to Romanes, "to accept Darwin's view that their origin is to be sought in consciously intelligent adjustments on the part of ancestors." He cites the case of a species of wasp of the genus *Sphex*, which paralyzes caterpillars by stinging them in each of the nine minute nerve centers before depositing them in the cells for the larva to feed upon. He regards it as impossible that such an instinct could have arisen by natural selection unaided by originally intelligent action. In regard to this it may be said that, if the complicated maternal instinct of the *Sphex* wasp is an "inherited habit," its ancestors must not only have possessed great industry, but also a very remarkable knowledge of anatomy. Moreover, it has been shown (1898) by Mr. and Mrs. Peckam ("Instincts and Habits of the Solitary Wasps") that the instinct of *Sphex* is not so exact as was formerly supposed. Not only is there a great deal of individual variation in the instinct of this species, but there is a gradation from this through other genera to those having much simpler instincts. They have shown that instinct may be acted upon by natural selection, just as may any other function or structure.

Man.—*Zoological Position.*—In the classification of the animal kingdom mankind is comprised in the species *Homo sapiens* of Linnaeus, and placed in the class Mammalia, and order Primates. Mammals of this order are distinguished by being plantigrade, pentadactyle, with opposable pollex, and by having complete dentition with two pairs of incisors on each jaw, bunodont premolars and molars, and the orbit completely separated from the temporal fossa. The brain is large, the cerebral hemispheres covering the cerebellum. There are two thoracic mammæ, the uterus is without horns, and the placentation is metadiscoidal.

The Primates may be divided into several families and it is a question of judgment whether Homo should be placed in a family by itself or grouped with its nearest allies. A. Sedgwick puts Homo in the family *Anthropomorphidæ*, which includes the gibbons, orang-utan, gorilla, and chimpanzee. In distinction from the other Primates these animals share with man the following characters: Erect position, absence of a tail, absence of cheek pouches, dental formula $i\ \frac{2}{2}$, $c\ \frac{1}{1}$, $p\ \frac{2}{2}$, $m\ \frac{3}{3}$, bony external auditory meatus, cerebral hemispheres projecting backward beyond cerebellum, stomach simple, and cecum small with vermiform appendix.

The genus Homo differs from the other Anthropomorphidæ chiefly in two characteristics: (*a*) differentiation of the hands and feet, and (*b*) greater size and complexity of the brain with associated

mental power, including speech and ability to use tools. In detail Homo is distinguished by having fore limbs shorter than hind limbs, carpus without a centrale, hallux not opposable, canine teeth not projecting and not separated by a diastema from the premolars, maxilla and premaxilla fused, mental protuberance at the symphysis of the lower jaw, projecting nasal bones, cranium large, without sagittal and occipital crests and with foramen magnum looking directly downward, brain much larger and with more complex convolutions than the apes, hairy covering reduced chiefly to special regions, no vocal sacs; and by walking erect on the soles of the feet and being able to speak.

Men differ greatly in different parts of the world, so much so that they would be classed as different species if it were not for the fact they are all able to breed together. Interracial sterility having been proved to be absent, all the various races must be classed as variations of one species.

Evolution of Man.—The evidence that man has arisen by the process of organic evolution, and has not been especially created, is of the same character as the evidence in regard to any other animal. Such evidence may be found in the study of comparative anatomy, vestigial organs, and embryology. Some of this evidence has been indicated in the previous paragraphs relating to the zoological position of man. The human body contains many structures which are feebly developed and are apparently of little or no use. These vestigial structures represent parts which are fully developed and functionally important in the lower animals, and clearly point to a course of evolution from pronograde ancestors. Adequate discussion of this evidence being impossible here, owing to lack of space, the reader should consult Wiedersheim (1895) and Keith (1912).

Phylogeny of Man.—Granting that man has been evolved with the rest of the animal kingdom through the orderly operation of natural processes, it becomes of great interest to know what has been the history of human evolution. Paleontology has furnished direct evidence from which can be reconstructed almost complete histories of the evolution of the horses, camels, elephants, and many other groups of mammals. But we are less fortunate in regard to the Primates, few fossil remains having been found. So that in any attempt to reconstruct the phylogeny of this group, reliance has to be placed chiefly on comparative anatomy and embryology. Summarizing the results obtained in this way, we may say that Hubrecht (1897) finds evidence on embryological grounds that the earliest Primates were creatures something like the rare little arboreal *Tarsius spectrum* of Borneo and Sumatra. Cope found in the lower Eocene strata of the United States a fossil, Anaptomorphus, that resembles Tarsius. So it may be inferred that the main stem of the Primates arose in the early Eocene period perhaps in common with the ancestors of the Insectivora and the Rodentia. The Lemurs must have branched off very early for they have a very different type of placentation from Tarsius and the other Primates. These early Primates were doubtless arboreal animals, and like the present monkeys, had both pollex and hallux opposable, thorax compressed laterally, were provided with tails, and progressed on all fours, pronograde. The erect, or orthograde, posture with all or some of the structural changes that are implied by that posture must have arisen as early as the lower Miocene period, for in strata of that period have been found remains of an ape closely resembling the present gibbons. The gibbons (Fig. 2165) are very interesting, because they are the most primitive of the living anthropoid apes. They are arboreal animals not over three feet high, without tails, with the thorax flattened from back to front and the arrangement of visceral and abdominal muscles much as in man. Moreover they habitually [illegible] tion, swinging by their [illegible] legs along branches of trees [illegible] 1912).

The earliest known form of [illegible] is Dryopithecus, found fossil in middle Miocene strata. From anatomical evidence [illegible] the large anthropoids—orang, gibbon, chimpanzee—to have been evolved [illegible] of man from a common, perhaps gibbon-like, [illegible]. The anthropoids became more closely adapted to arboreal life, while the ancestor of man took to a terrestrial life, with the result that the hands became more perfect prehensile organs, and the feet became better adapted for locomotion on the ground through loss of motility in the hallux and other changes.

Fig. 2165.—A Gibbon, *H[illegible]* [illegible] (From H. A. [illegible] Wood.)

One of the most striking facts brought to light by the study of mammalian fossils is the great increase in the size of the brain which took place independently in different groups of mammals during the Tertiary Era. The Primates were preeminent in this respect, and in man the brain reached its highest development. That this development came comparatively late in the phylogeny of the human species may be inferred, if it be assumed that the Pithecanthropus, known from an imperfect skeleton found in early Pleistocene strata in Java, is in the direct line of human descent. The brain of this man-like animal was little more than half the size of the modern human brain, but the thigh bone is absolutely human, and presumably the feet, which unfortunately are missing, were like ours.

In Europe men lived before the beginning of the Pleistocene, or glacial, period, as is shown by the presence of flint implements, but the earliest known fossil that is undoubtedly human is a jaw bone found in early Pleistocene strata near Heidelberg. This man belonged to what is known as the Neanderthal type, with a large brain, but more primitive than modern man. Some authors regard this type as constituting a distinct species, to which the name *Homo primigenius* has been given.

Modern man, the typical *Homo sapiens*, first appeared after the close of the Pleistocene, and his remains are found all through the Recent period, a period estimated by various authors to have extended back from 15,000 to 150,000 years. This completes the evolution of the human body. The progress that has taken place from the beginning of the Recent period down to modern times is progress in mental development, and in the arts and civilization.

Conclusions.—As to the origin of life upon this globe we know nothing, and when we consider the enormous complexity and peculiar characteristics of protoplasm, the living substance, it does not seem probable that the answer to this question will come from a chemical laboratory. Much has been written on the subject, and we are indebted to Troland (1914) for a very ingenious hypothesis based on the conception of autocatalysis and the action of enzymes, but while very interesting this is all pure speculation.

On the other hand, taking it for granted that organisms of a simple type, having all the essential qualities that we regard as characteristic of living beings, have become established on the surface of the earth, we have good evidence, first, as to the fact that they have increased in complexity of structure, in diversity of character, and in adaptability to the conditions of life; and, second, from observation and experiment, we are able to construct a reasonable theory as to the manner in which this process of organic evolution has come about. Moreover, it has been shown that, while man is peculiar in many respects, he nevertheless occupies a definite place in the scale of the animal kingdom, has similar relations to the past, and in all probability has been produced by the same process of evolution that has been operative in the development of the various other species now inhabiting the earth.

As to the method of evolution, it may be said that in the opinion of the majority of naturalists today, while acquired characters are of great importance to the individual, and their periodic recurrence in successive generations may be necessary in the formation of coadaptations as an aid to natural selection, the *inheritance* of acquired characters is not only not the prime factor in evolution, but that it is not a factor in any degree.

Differential fertility appears to be an important factor, being, according to the circumstances, either an aid or a hindrance to evolution; preferential mating may be the best explanation of the origin of certain secondary sexual characters; and some form of isolation must be present, or else divergent evolution is impossible, and without isolation it would be impossible to explain the differentiation of species by characters of less than selective value; but the chief cause of organic evolution is to be found in germinal variation and heredity controlled by natural selection, or the survival of the fittest in the struggle for existence.

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Exalgine is orthomethylacetanilide, or methylphenyl-acetamide, $C_6H_5N(CH_3)CO.CH_3$, and is therefore a derivative of acetanilide. It is prepared by heating monomethylaniline with acetyl chloride, and occurs as colorless crystals having a faintly aromatic odor and a saline taste. It is slightly soluble in cold water, more soluble is hot water, and freely soluble in alcohol. The chief use of exalgine is as an analgesic in sciatica, lumbago, neuralgia, migraine, tabes dorsalis, and rheumatism. It was formerly used as an antipyretic, but as it required somewhat large and toxic doses to produce the desired effect the drug has been replaced by safer preparations. The dose is from a half to one or two grains (0.03 to 0.13 gram.), and it is best ad-

ministered in pill form, with glucose as an excipient. According to Marandon de Montyel, its influence on digestion is slight; if the stomach is empty, an increased flow of saliva may be caused and also a feeling of constriction in the epigastric region. Vertigo, flashes of light, and tinnitus aurium are induced; cyanosis, numbness, formication, and a sensation of cold may be noticed. The action of the drug is rapid, and the effects pass off equally rapidly.

R. J. E. Scott.

Examination, Physical.—See *Diagnosis, Physical.*

Examiner, Medical.—See *Coroner.*

Examining and Licensing Boards.—See *State Medical Licensing Boards.*

Exanthemata.—This is the term applied to a group of infectious diseases in which a characteristic eruption constitutes the most striking manifestation. The term "eruptive fevers" is also applied to the group. The exanthemata are generally regarded as including the following five diseases: measles, scarlet fever, German measles, smallpox, and varicella. To these may be added the so-called "fourth disease" and erythema infectiosum. Some writers include among the exanthemata typhoid and typhus fevers.

The exanthemata are noted for their high degree of infectivity. They are transmitted by direct contact as a rule, and occasionally through the agency of fomites. Scant belief is nowadays accorded to the idea of aerial transmission. Individuals differ as regards their susceptibility to these diseases, one attack of which as a rule confers life-long immunity. These diseases affect principally children. Civilized races enjoy a relative immunity to [illegible] as evinced by the fact that when one [illegible] is introduced among a tribe or [illegible] which it has never as yet appeared [illegible] with unusual rapidity and acquires [illegible] virulence.

The course of any one of the [illegible] marked by four stages, as follows: [illegible] of *incubation* is the time that elapses between the entrance of the specific virus into the [illegible] the appearance of the first symptoms of the [illegible] The *prodromal* period or period of *invasion* represents the time that extends from the appearance of the first symptoms to the appearance of the eruption. The stage of *efflorescence* begins with the appearance of the eruption and ends with the recession or fading of the latter. The period of *desquamation* coincides with the gradual fading and disappearance of the rash and the exfoliation of a part of the integument. These four periods are characteristic in each of the exanthemata. They have a duration that varies between certain limits in each of these diseases. Scarlet fever has the shortest period of incubation (two to seven days) and German measles the longest (fifteen to twenty-one days). In measles, smallpox and chickenpox the incubation periods are nearly the same, being respectively eight to twelve days, twelve to fourteen days, and ten to fourteen days. The prodromal period is the shortest in German measles and chickenpox, being twenty-four hours, and longest in measles and smallpox, being respectively three to four days and four days. In scarlet fever the prodromal period varies from twenty-four to thirty-six hours.

The following table contrasting the exanthemata is taken from the work on "Diseases of Infants and Children" by Chapin and Pisek:

Table of Exanthemata.

	Scarlet fever.	Measles.	German measles.	Smallpox	Chicken-pox.
Incubation	2 to 7 days. Usually 2 to 4 days.	8 to 12 days. Usually 10 days	15 to 21 days	12 to 14 days	10 to 14 days
Prodromal stage.	24 to 36 hours	3 or 4 days	24 hours	4 days	24 hours
Throat and mucous membrane.	Intense hyperemia and typical punctate rash on fauces and posterior pharyngeal wall. Raspberry tongue.	Koplik's spots. Red throat.	Nothing typical....	Red papules on palate and fauces.	Red papules on palate and fauces
Distinctive prodromal symptoms.	Sudden onset with intense symptoms. Sore throat. Vomiting. Convulsions.	Gradual onset. Coryza. Cough.	Slight or none at all.	Sudden onset. Intense symptoms Backache.	Slight [illegible]
Character of eruption.	Uniform erythema with minute puncta.	At first isolated red papules coalescing with intervals of normal skin, giving a blotchy appearance.	Slightly raised red macules not coalescing.	Hard shotty papules, in 2 days becoming umbilicated non-collapsible vesicles and in 4 days pustules. Total cycle, 6 days	Papules [illegible] becoming [illegible] in a few hours. Seldom [illegible] Individual lesion [illegible]
Topography of eruption.	Appears first on chest, spreading to rest of body. Least intense on face.	Appears first on face. Spreads to whole body.	Appears first on face. Spreads to whole body.	Appears first on [illegible] head and wrists. Spreads on [illegible] on arms. [illegible] on trunk. All [illegible] same stage [illegible] tion.	[illegible] time in any one
Desquamation	Large flakes and sheets pin-holed.	Fine. Furfuraceous.	Slight or none.	Crusts [illegible]	[illegible]

The specific agents that give rise to the various exanthemata have as yet eluded discovery. Most authorities regard the morbid factors as protozoa rather then bacteria. The present tendency is to attribute the infectivity to droplets from the upper and lower respiratory tracts, and to discount the idea of infection from scales of skin cast off during desquamation. The modern methods of isolation and terminal disinfection are based upon these conceptions. It has been found quite feasible to treat different forms of exanthemata in the same hospital ward, provided that contact between the individual beds is prevented by glass partitions, not necessarily reaching to the ceiling, and provided that the nurse and medical attendant carefully disinfect their hands after these have been in contact with any patient. Municipal health boards have largely abandoned the practice of fumigating the sick-room after the termination of quarantine in measles and diphtheria, relying upon the element of time, the efficacy of free ventilation and sunlight, and the value of thorough cleansing of the sick-room.

The period of incubation in the exanthemata is commonly regarded as a latent one, the affected individual appearing perfectly well. Nevertheless, careful examination may reveal evidences of infection. One manifestation of this period which has recently been pointed out is a moderate enlargement of the superficial lymph nodes. Examination of the blood shows distinct changes in its cellular ratios. There can be no doubt that during the incubation period profound changes are going on in the body, changes that point to a combat between the host and its parasites. Recent observers have called attention to a close analogy between the symptoms characterizing the period of invasion of such a disease as measles, and the manifestations of allergy or anaphylaxis. The conjunctivitis, the catarrhal symptoms of the upper and lower respiratory tracts, and the eruption have, indeed, a good deal in common with the symptoms of serum sickness.

Claude Buchanan Ker in "A Manual of Fevers" discusses the subject of confusing other rashes with the exanthemata. He states that, "in the first place, it is always possible that the *prodromal* rash of one disease may be mistaken for the true eruption of another. Thus scarlatiniform prodromal rashes occur in measles, chicken-pox, and smallpox, and lead to many mistakes, the difficulty of their recognition being enhanced by the fact that the patient may suffer from marked constitutional disturbance. Secondly, the large group of *drug rashes* has to be remembered. Thirdly, the various types of *serum rashes* may resemble very closely certain of the exanthemata. Fourthly, *enema rashes*, due to absorption from the intestine, may cause difficulty, as do the rashes of a similar nature which occasionally follow a dose of salts or some other hydragogue cathartic. Fifthly, we have *food rashes*, such as those due to eating shellfish or various articles of diet in regard to which an individual patient may possess an idiosyncrasy. Sixthly, *septic rashes*, such as sometimes follow burns or are noticed in septicemic conditions, must not be forgotten. And lastly, various skin conditions, which cannot be specified in detail, such as multiform erythema from various causes, roseolar and pustular syphilides, herpes, acne, and pemphigus, may be mistaken for one or other of the exanthemata."

ALEXANDER SPINGARN.

Excipients are substances, more or less inert, which are added to give the necessary consistency and adhesion to drugs administered in pill form. As a rule the choice of an excipient is left to the pharmacist. Excipients are divided into two classes: (1) Liquid and semi-liquid excipients; and (2) solid excipients. The liquid and semi-liquid excipients in general use are water, glucose, syrup, mucilage of acacia, glycerin, glycerite of tragacanth, and honey. The chief solid excipients are bread, crumb, soap, cacao butter, confection of rose, and marshmallow. Undesirable excipients are Canada balsam, wax, paraffin, fats, and magnesia.

R. J. E. SCOTT.

Excisions.—The term excision (*ex*, out or from, and *cædo*, I cut), as applied to osseous tissue, represents a conservative attack upon injured or diseased bones or joints, which is performed generally in lieu of formal amputation.

Excision and resection are terms frequently employed synonymously and interchangeably, but this is inaccurate. *Excision* is a broad term, meaning the "removal of an offending part without that total ablation of the affected portion of the body which is implied by the term amputation" (Ashhurst). *Resection* means "an operation which takes away a middle portion and brings the ends together again and is thus in strict surgical language limited to partial excisions of the long bones" (Ashhurst).

The immense importance of this operation in modern surgery is immediately appreciated when it is recalled that many limbs which were formerly sacrificed are now preserved and restored to usefulness. It involves the removal of bone or joint structures which are diseased, or are incompatible with the future utility or the symmetry of the part. Broadly speaking, the indications are included under three great heads: trauma, disease, ankylosis.

Excision in trauma was recommended by Hippocrates for compound fractures or luxations, and later by Celsus and by Galen. Rhazes was probably the first to recommend excision for disease, in a case of spina ventosa (Ashhurst). According to the same writer, the first modern record of an excision for compound luxation was made in 1750 by Mr. Cooper of Bungay, who successfully sawed off the ends of the tibia and fibula, instead of amputating, in a case of compound luxation of the ankle in an elderly man; and some years later (1762) Mr. Filkin, of Norwich, performed the first recorded excision for disease, in a case of long-standing caries of the knee.

Henry Park (1782) and Moreau (1786) were early advocates of this method of treatment, but little was done, however, until Syme in 1831 in the elbow, and Ferguson in the hip, knee, and wrist, made use of this operation as a conservative surgical procedure.

Excision of a bone may be partial or complete, according to the extent of the pathology. Excision of a joint implies the ablation of the articular extremities of the component bones with, of course, the cartilage and the synovia. There are two methods of performing excision—the open and the subperiosteal. In the open method the periosteum, tendons, and often ligaments are sacrificed; while it is more rapid, yet the functional result is necessarily not so good. In the subperiosteal method the periosteum (or the articular capsule) is preserved, thus conferring additional support and movement. Practically, however, the periosteum is elevated more or less in shreds, except in young bones, where it is thick and loose. Until recently, it was thought that periosteum produced new bone, but now it is regarded as a limiting membrane (Macewen).

The epoch-making advances in the surgery of the bones and of the joints have revolutionized the indications, contraindications, and results of excisions. Thus, while trauma, disease, and ankylosis are to-day, as formerly, the chief indications, yet in trauma, for example, asepsis and antisepsis have greatly reduced the number of compound fractures or luxations that require operation, and modern methods of reduction diminish the number of irreducible luxations as well as of deformities after fracture; in irreducible and ununited fracture the use

of bone plates obviates the necessity of excision; and after resection for disease, the grafted intramedullary bone splint in the case of bones, and the transplanted fat-fascia flap interposed to form a new capsule in the case of joints, have contributed greatly to perfection in results. So, too, advances in the understanding and the application of the principles of massage and of passive motion, and their more widespread employment, have lessened the number of cases of true ankylosis.

Excision finds its principal application in joint disease where, according to Ashhurst, it is indicated when an articulation is so much diseased that the recovery of the patient depends upon its removal; and occasionally in cases in which, while the extent of disease is not sufficient to justify an amputation, the length of time which would be necessary for the obtaining of a spontaneous cure would be such as, of itself, to warrant operative interference, or in which the result of a spontaneous cure, if obtained, would be less satisfactory as regards the usefulness of the limb than the result of an operation.

Excision is contraindicated, according to Ashhurst, by the extent of osseous disease being so great that its entire removal would forbid the hope of retaining a useful member. Many of these cases are restored to usefulness nowadays by intramedullary bone-splinting. Extensive disease of the soft tissues around a joint, abscesses and numerous discharging sinuses may prevent a good result after excision. In the extremes of age excision does not give good results. Extensive chronic visceral disease and pulmonary tuberculosis are contraindications to excisions, just as to other operations. Under such conditions, if operation must be performed, amputation is the method of choice.

In deciding for or against excision, the occupation of the individual is a factor. For instance, in a maimed laborer individual judgment must be called upon to decide whether an amputation may not give greater future usefulness than an excision. This question often arises in the consideration of diseases or injuries about the ankle-joint. Thought must also be given to the habits, present condition, constitutional taints, etc. Even the oversensitiveness of the patient to deformity should have some weight.

In excisions upon young persons the epiphyseal cartilage should be preserved, for if the whole epiphysis be ablated the limb in its growth may assume fantastic shapes. Epiphyseal growth is not so apt to be impaired at the elbow, hip, and ankle as at the shoulder, wrist, and knee. In this last instance, *arthrodesis* is the operation of choice, firm, bony union between the femur and tibia being sought. *Arthrectomy* is preferable to excision in growing children.

In tuberculous joint disease excision is reserved for the severer cases, and is to be used only—(1) Where mechanical treatment has failed to relieve symptoms; (2) where a sequestrum involving a large part of one of the articular ends is present; (3) where drainage by other means fails and sepsis is present; and (4) where the general condition is rapidly failing and radical measures are demanded (Lovett, in "Keen's Surgery").

In *acute* suppurative arthritis and synovitis excision is never indicated, but in *chronic* suppurative joint disease this operation may be done to remove the disease and to relieve the deformity. In arthritis deformans, excision may be done for the flail joint but the rarefying osteitis must run its course, however, in order to give a solid ankylosis. In chronic rheumatoid arthritis excision has been occasionally performed. In gunshot and other injuries excision is always preferable to amputation but the expectant treatment is always the initial method and with present-day precision in cleanliness the necessity of this operation rarely arises. In bone and joint disease dependent upon lesions of the central nervous system any form of partial or complete excision is usually followed by [illegible] Murphy, of Chicago, has recently [illegible] on Charcot joints.

In malignant bone disease [illegible] particularly if the diagnosis [illegible] early. An early excision is of more value than a late amputation. If metastases have taken place, amputation offers nothing better than excision. If metastases have not taken place, the sooner the tumor is removed the better; and it is necessary to remove only the tumor. If, after excision, the resources of plastic surgery fail to restore usefulness of the limb, the worst that can come is the removal of a [illegible] member (Warbasse, in "Keen's Surgery"). Excision and resection are destined to lower the mortality of malignant disease.

The *incision* should be large enough to permit free exposure of the part, and should be placed in intermuscular planes, to minimize the destruction of tissue. Incisions should be planned so as to include the opening of a sinus, if one exists. Important blood-vessels and nerves should be carefully avoided In arthrodesis, which is the artificial production of ankylosis, the fate of the tendons that control the joint is immaterial, but if mobility be desired after excision, the tendons and muscles should be carefully preserved, the former being cut obliquely, to make subsequent suturing easier.

Incisions should be so situated that the entrance through the capsule and into the joint is the most direct one. Gentleness should always be exercised throughout the operation. Maltreatment of the soft tissues not only interferes with the process of repair, but destroys an otherwise successful result. Care should be used in protecting the soft parts from the saw. The tendons, if possible, should be left undisturbed within their sheaths. Their insertions should be left in continuity with the periosteum, or a small piece of bone (Vogt) may be removed with the insertion. If muscles must be divided, they should be cut in the direction of their fibers, the nerve being avoided. If this is impossible, they may be divided transversely or obliquely as near their origin or insertion as possible.

The management of the periosteum is still in dispute. Some advocate the subperiosteal, others the parosteal method. It must be remembered in any given case that the value of the periosteum in producing bone is variable, and is dependent mainly: (*a*) Upon age. The healthy physiological periosteum has but little osteogenic power except in youth. (*b*) Its power to develop new bone depends upon the thickness of the different bones. (*c*) Pathological processes involving the periosteum and causing a thickening of the osteogenetic layer will increase its osteogenetic power. In but few cases can a comparison be made between these methods with reference to these three points; and, since many subperiosteal operations are very imperfectly performed, it is not surprising that a division of opinion should exist.

Ollier, Langenbeck, Sayre, and others have long insisted that the traumatism produced by the subperiosteal (*i.e.* subcapsuloperiosteal) method was less than by the parosteal method, and have maintained that the reparative process itself was less impaired because of the protection to the soft parts afforded by the capsule and periosteum.

Ollier has shown that the regenerative process is considerably influenced by the manner in which the periosteum is raised. A blunt elevator lifts practically nothing but the elastic tissue of the periosteum, but with a sharp rugine not only is the osteogenetic layer raised but also the superficial bony lamella just beneath it. Kocher attempts, where possible, to preserve the cortex of the bone, securing thereby a germinal layer for [illegible]

Modern opinion favors the subperiosteal method for the protection to the tissues, for the production

of new bone, and for the aid to the reparative process. Time is not sacrificed in the subperiosteal method, for the separation of the periosteum can be rapidly accomplished by a to-and-fro motion of the rugine. When one approaches a prominence of bone or a tendinous insertion is met, a small piece of bone may be separated with the periosteum by the chisel or the rugine; such a piece may act as a center of bone growth. (König and Tiling.) During the separation the rugine is to be pressed against the bone, lifting the periosteum entire and not injuring its connection with the overlying tissues.

In the management of the bones, we strive to remove the smallest amount of bone which will abate the disease or correct the deformity. Frequently the gouge or curette is adequate to remove the carious or necrotic areas. Caution to preserve the integrity of the epiphyseal line has been alluded to above and must always be borne in mind. Where the bones can be protruded through the incision and the soft parts sufficiently protected, the Butcher, the Emmerich, or the broad flat-bladed saw (carpenter) may be used. When the bones cannot be displaced and the protection of the soft parts can be secured by gentle traction, the Gigli saw can be used. Other varieties of saws seem scarcely necessary in excisions. The sawing is usually done in plane surfaces at right angles to the line of pressure. In some instances, especially where an attempt to obtain motion is made, mortises and tenons are fashioned, which tend to favor retention of the fragments and to preserve the shape of the joint ends of the bone.

In pathologically involved joints, after removal of the articular ends, further removal of foci may be required with the gouge or spoon. After removal of the disease from the bones their fixation is necessary, either in the attempt to obtain motion or in that to secure ankylosis. For this purpose, silver, copper, aluminum bronze, wire, steel and steel-plated nails, bone pins (Marsh), and steel drills (Wyeth's) have been used. Generally fixation is not necessary for a longer period than ten to fourteen days, and in the majority of cases in which good appliances are obtainable the fixation is not required, in aseptic cases, for a longer period than that during which the first dressing must be kept applied. Chromicized catgut, which is prepared to resist absorption for from two to three weeks, is therefore the fixation suture of choice in the great majority of excisions. It should be the strongest and heaviest obtainable and should be thoroughly examined bacteriologically for microorganisms. The presence of a foreign unabsorbable body, if pathological deposits exist in the bone, only offers a *locus minoris resistentiæ* for infection from within or without. In some instances, as in the hip-joint, or knee-joint, it is not always feasible to produce fixation by the catgut suture. Here the steel nails, drills, or bone pins may be used. The bone pins are absorbable.

The management of the synovial membrane, capsule, and ligament requires the removal of all pathological deposits affecting them, even if it include the entire ablation of these parts. When possible, the synovial membrane, the capsule, and the ligaments should be saved in part or entire, since the perfection of motion in nearthrosis depends in no small degree upon the presence of these structures.

Where a considerable length of the shaft of a bone has been excised, a true resection, shortening and subsequent loss of function may be prevented by inserting a bone autograft, which is most conveniently obtained from the crest of the patient's tibia. The periosteum may or may not be removed from the graft. Murphy states that if the graft is taken from young individuals the periosteum has a plus osteogenetic influence, neutral in middle, detrimental in old age. The graft is usually inserted into the medullary cavity, and for it to "take" it is essential for it to be in contact at one end with the living osteogenetic bone it is to aid. The graft is *per se* not *osteogenetic*, but *osteoconductive*. It acts as a scaffold for the capillaries and blood-vessels with their living osteogenetic cells, as they advance from the living bone at both ends into the transplant. New lamellæ are deposited around the new capillaries and these fit into and adjust themselves in the graft. It will scaffold the production of new bone even into the joint when it is surrounded by the capsule, and tuberosities are produced in about the regular location. The transplant is always ultimately absorbed. If muscular control is expected after union of the graft, the musculo-tendinous attachments should be accurately sutured to it at the point of desired union.

The transplant is usually the size of the adult index or middle finger, about three-eighth by one-half by five-eighth inches, and of desired length. The defect in the crest of the tibia from which this graft is removed fills in rapidly, so that after four to six weeks the site can scarcely be detected. Before inserting it the medulla in the ends of both fragments is reamed out to the desired size and depth. The transplant is driven into one of the fragments far enough to allow the other end to be inserted into the opposite fragment. It may be held *in situ* by a bone or iron nail driven through it transversely. It requires about forty to sixty days for the graft to become firmly attached, and a gypsum case should support the limb during this time. It takes from seven to ten months for a bone to be fully restored to the normal size. The above details are obtained from Murphy's experimental and clinical observations.

In the absence of infection and where the excision has been performed under the most rigid aseptic precautions, no drainage is necessary. Where serous or bloody oozing is anticipated, a drain, preferably of rubber, may be inserted for twenty-four hours. In the presence of infection, drainage should be instituted for a longer period of time. Free drainage of a joint should be avoided wherever possible for, according to Murphy, it is followed, in ninety-six per cent. of cases, by ankylosis or synechiæ of the synovial membrane as a final result. In the after-treatment rest should be secured by immobilization by a splint or by a gypsum case. In the artificial production of ankylosis (arthrodesis) prolonged fixation is necessary, but where a movable joint is sought for, as soon as the wound is healed the splint should be removed and movement encouraged.

In order to preserve mobility marked advances have been made within the last decade by the so-called interposition operations, by which a portion of the joint capsule, or muscle, or tendon has been utilized to prevent adhesions. A brief and an incomplete genesis of this subject may be presented in this connection. In 1826 Barton of Philadelphia did an osteotomy of the neck of the femur for ankylosis of the hip-joint and prevented union by persistent movements. In 1830 Rodgers of New York modified this operation by removing a disc of bone from between the trochanters, and in 1840 Carnochan tried to secure mobility of the jaw by interposing a piece of wood. Apparently Verneuil was the first to attempt the modern interposition operation when he detached and interposed a portion of the temporal muscle and fascia between the condyle and the glenoid in a case of ankylosis of the jaw. Some thirty years later Helferich revived Verneuil's operation on a child a year old, and in 1895 Mikulicz modified it by using a flap of the masseter for the interposing structure. In 1901 Cramer operated on ten cases of ankylosis of the patella and by interposing a flap from the vastus internus he secured good results in six; in the same year Orlow employed metal plates and gold foil to secure joint mobility. Other non-absorbable materials were used for this purpose, such as zinc, silver, celluloid, rubber, etc., but as a rule the results were disappointing, since in a few

months the foreign body was discharged and the ankylosis returned. Chulmsky in 1902 tried to use decalcified bone, magnesium, and ivory but he was unsuccessful. However, he drew the useful deduction that, inasmuch as false joints after fracture were formed of aponeurosis and fatty tissue, the same tissues should be used to create mobility in ankylosis. In the same year Nélaton (*Bull. et Mem. de la Soc. de Chir.*, 1902) operated on two cases of hip ankylosis employing a strip of fascia lata between the head of the femur and the acetabulum.

Especially noteworthy have been the investigations and experiments of J. B. Murphy of Chicago, whose work started in 1901. In 1905[1] he reported twelve cases in which he had attempted to create "normal movable joints with capsules and collagen intra-articular fluid" by the interposition of a flap of fascia and muscle covered by a layer of fat. By this method hygroma-bursa structures are sought which will serve to make the joint movable. His theory is that the formation of hygroma is the result of a degenerative process in fatty tissue with hyperplasia of the connective-tissue element, and a subsequent liquefaction of the hypertrophied connective tissue.

Animal tissues from extraneous sources have been used by Baer and Osgood, such as Cargile membrane, or chromicized pig's bladder, but, as a rule, these tissues have been too quickly absorbed. Of the two the latter substance is the better and may be used sometimes with perfect propriety (Baer[2]).

As to the field of usefulness of the modern interposing flap operation it is much too soon to dogmatize. It is important in its consideration to divide ankylosis for practical purposes into two groups, the false or periarticular, and the true or intraarticular. Murphy further divides the periarticular into capsular and extracapsular, and the intraarticular into synovial, fibrous, cartilaginous, and osseous. As has been well summarized by H. R. Owen,[3] the fascia-flap operation has no place in the relief of periarticular, extraarticular or false ankylosis, but such measures as baking, massage, passive exercise, manipulation under an anesthetic, tenotomy, myotomy, tenoplasty, myoplasty, and excision of tendon sheaths or cicatrices are the proper forms of treatment. As to intraarticular, or true ankylosis, Owen states that operation must depend upon the cause, the joint affected, and the present usefulness of the limb. If the cause is the commonest of all causes, tuberculosis, it is well to hesitate, even though years have elapsed since active signs of tuberculosis have been seen, on account of the danger of relighting the tuberculous process. In the active stages of other infections, operation should not be done. The temporomandibular articulation offers the best field for the fascia-flap operation, or the animal tissue interposition operation. Next in order, both as regards necessity and outcome, are the hip-joint and shoulder-joint. Ankylosis in either location is a serious handicap and inconvenience and the Murphy method is the best avenue of escape. According to Murphy's statistics, the knee and the elbow offer the poorest prognosis of any joints, and therefore in light of our present knowledge the fascia-fat operation should be avoided unless there is serious interference with occupational usefulness, humiliating deformity, or continued pain. If any or all of these causes decide the question of operation affirmatively a full explanation should be made to the patient that operation in these joints is apt to occasion pain over a long period, that the degree of motion obtained may be disappointing, and that ankylosis may recur.

Lexer, of Königsberg, has reported a case in which he transplanted from a fresh amputation both bones and the knee-joint with the crucial ligaments but without the synovial membrane. Healing occurred and after considerable flexion had been developed two secondary operations were done to improve the extension, in the first a portion of the [illegible] was turned down, and in the second the [illegible] was turned up. Fair extension was obtained. [illegible] has also transplanted a large piece of [illegible] half the joint and has demonstrated its feasibility.

Buchmann has successfully transplanted the [illegible] metatarsophalangeal articulation and its [illegible] bones to the elbow for ankylosis in the same individual, and Bloodgood has imitated him with a good result. Even more extraordinary is the case reported by Kuettner to the Breslau Surgical Society, in which he removed the upper third of the femur and the hip-joint for chondrosarcoma and replaced the removed structures by a hip-joint obtained by autopsy eleven hours after death and which had been kept in salt solution and chloroform for twenty-four hours before it was implanted.

The *instruments* which are specially used in excisions or resections are: 1. Those which divide the soft tissues immediately investing the bone—joint-knives. These should have strong handles and short-cutting blades to insure precision and force in action. 2. Those intended to detach the periosteum from the bones—rugines. 3. Those intended to fix the bones while the soft parts are being detached and the bones sawed. 4. Those intended to divide the bones. When the bones can be displaced and a straight saw can be applied, either a bow-saw with a rotating blade or a solid straight-back saw may be used. When the bones cannot be displaced so that a straight saw can be used without injuring the soft parts, the chain saw or the Gigli saw should be used. The former is used when the surface to be cut is in one plane; the latter when the cut surface is to be concave or convex. Electrically propelled saws seem to have no great advantages in excisions, but the use of burrs with the surgical engine often is advantageous in quickening and lightening the mechanical work. 5. Those intended to cut away spicula or prominences of bone with the periosteum attached: (*a*) bone forceps; (*b*) chisels. 6. Those intended to remove diseased foci in the bone after the sections are made: (*a*) gouges; (*b*) spoons. 7. Those intended for drilling the holes required for the wire nails or catgut suture.

During the operation the Esmarch bandage is a great help in exsanguinating the field of operation. It allows a complete inspection and renders possible careful dissection of the tissues. It must be used with discretion, and must not be employed upon those whose arteries are diseased. Again, the exsanguination of the tissues should not be extended over a great length of time. This can be avoided in a measure by the more rapid work which it renders possible. It is well to remove it in prolonged excisions before the operation is completed. After removal of the bandage there is some vasomotor paralysis, but it soon yields or is corrected by elevation of the limb. In applying the bandage, very great care must be used to avoid direct compression of the motor and sensory nerves between the bone and the bandage.

The functional results of excisions are usually classed as: (1)Bad. This includes cases in which the bones remain at a distance from one another and are held together by fibrous bands only. The limb is without muscular control and cannot be used. (2) Mediocre. This includes cases in which there is also a pseudarthrosis, but the fibrous union is short and strong. The joint is flail, but nevertheless it obeys the muscles in many ways and can be made useful by apparatus. (3) Good. This includes those cases in which there is a nearthrosis and a sufficiently perfect one to differ from a normal joint only in the extent of the motions.

In most excisions ankylosis is the common result and is in some joints to be preferred to any other result than the ideal one. Flail joints are rare. Mediocre results are common.

In the following description in detail of the indications, the anatomy, and the operative technique in the excision of the important joints of the body, it must be borne in mind that the day of typical excisions is rapidly passing to its close, and that with marked precision in asepsis, in care of periosteum and nerves and tendons, in improved after-treatment, there has come increased latitude in the formal excisions. The rule of to-day is to remove nothing but the diseased soft parts and bone and to do it with the minimum disturbance of the adjacent structures. Modern surgical practice is not to make the disease or injury come within some fixed method of excision but there is a strong tendency toward individual study of the condition, and an adaptation, within a very wide range, of the operative measures which are applicable. This leads to many "atypical" excisions, and while the term is misleading in suggesting some irregularity in performance, which of course there is not, yet the outcome is highly successful in many instances.

Excision of the Interphalangeal Joints of the Fingers.—The most important of these joints is that of the thumb.

Indications.—Complete destruction; chronic tuberculous arthritis; chronic suppurative arthritis; chronic non-suppurative arthritis.

The preferable situation for the incision is the dorsolateral aspect of the joint, somewhat nearer the dorsal than the palmar surface, because the digital arteries and nerves lie closer to the flexor tendons. The incision may be a single one upon the internal surface of the thumb and forefinger and upon the external surface of the little finger. Wherever fistulæ are present the incision may best be made so as to include them. The preferable method, however, is that of two incisions placed dorsolaterally, one upon each side of the extensor tendons. By means of these two the denudation of the bones and the exposure of the joint are easily accomplished, and, furthermore, if any amount of bone is removed the double incision prevents lateral deformity through subsequent contractures of a single scar. Each incision is carried through the capsule and the periosteum for the full length of the skin incision, which should extend above and below the joint sufficiently to expose and to dislocate the articular ends of the bones. With a sharp and curved rugine, the denudation of the bones is made from both incisions. Fine blunt retractors are used to expose the bone and to protect the separated periosteum and capsule and the tissues covered by them. When the capsule and periosteum have been freed sufficiently (subcapsuloperiosteal method), the ends of the bones are luxated without force through the more convenient of these incisions. The articular ends are now removed by the saw or cut away piecemeal by the bone-cutting scissors or rongeur forceps. After this is accomplished, the synovial membrane of the joint and the pathological foci in the soft parts about the joint are removed, preferably by dissection. The ends of the bones are now drilled, and one or two ten-day chromic-acid catgut sutures are inserted, bringing them in close apposition if ankylosis is desired. They are only loosely tied if an attempt at pseudarthrosis is made. In case a nearthrosis is desired, no sutures are necessary, as the suture of the divided periosteum and capsule will sufficiently hold the bones in their normal layer of tissue.

If an Esmarch bandage has been used, it is now removed. The larger vessels are secured. The periosteum and capsule are sutured with catgut. The remainder of the wound is closed, with catgut for the subcutaneous tissue and silk or silkworm gut for the cutaneous. Drainage is not employed unless suppuration is already present. An aseptic dressing is applied. A fixation splint is applied over the dressing. The gauze dressing is removed in ten days. At the end of two weeks all splints are removed. At the end of three weeks gentle passive motion is employed, unless ankylosis is desired.

Excision of the Phalanges.—Operations on these bones are seldom typical but the results are highly satisfactory. As they are usually done for dead bone, there is frequently found separation of the periosteum with the attached tendons and consequently function is but little impaired. In many of these cases the sequestrum may be removed through enlargement of the sinus already present. Where the periosteum is not loosened by disease its detachment is difficult. Partial excision of the phalanges, as is the case with the metacarpals, gives better results than complete removal.

The best method of excision of the terminal phalanx is by the U-shaped palmar incision, which begins opposite the distal interphalangeal joint line, and with the two limbs about three-quarters of the finger's width apart, terminates near the tip of the nail. The incision extends directly to the bone, a palmar flap is raised, and after scraping the bone free of as much of the periosteum as possible, the phalanx, or its diseased portion, is nipped off with bone-cutting forceps. The flap is sutured in place and the finger dressed on a palmar splint.

For the middle phalanx the incision is placed over the dorsal aspect, either to the inner or outer side of the extensor tendon, beginning just above and ending just below the adjacent interphalangeal articulations. In the index-finger the incision should be dorsoexternal and in the little finger it should be dorsointernal, so that presssure on the resultant scar may be avoided. The incision passes through the skin, fascia, periosteum, and the capsules of the first and second interphalangeal joints. The soft parts are elevated by a sharp rugine, preserving carefully the periosteocapsular sheath, the bone is disarticulated and removed, the periosteum and joint capsules sutured with fine catgut, and the skin margins closed with silkworm gut. A splint is used until osteogenesis has formed a new bone.

Excision of the proximal phalanx of any digit, save perhaps the thumb, is not admissible as a sound surgical measure.

Excision of the Metacarpophalangeal Joints (Fig. 2166).—Here also one or two incisions may be used. When one is used it is placed upon the radial dorsolateral aspect of the thumb and index finger, upon the ulnar for the little finger, and upon either side for the other fingers. If two incisions are used, they are made as in the interphalangeal joints, on each side of the extensor tendons. For the metacarpophalangeal joints a single incision will often suffice. If feasible the operation should be the subcapsuloperiosteal one. The incision is carried directly through the skin and subcutaneous tissue to the periosteum and capsule, of sufficient length to expose the joint well above and below. The digital nerves are avoided if seen. The short muscles passing between the metacarpal bone of the thumb and its phalanx, as well as the aponeurotic canal for the extensor and flexor tendons in the fingers and thumb, are also avoided. The capsule and periosteum are now exposed and are incised. The denudation of the periosteum and the elevation of the capsular attachments are carefully made, especially at the metacarpophalangeal joint of the thumb, in order that the muscular insertions may be preserved.

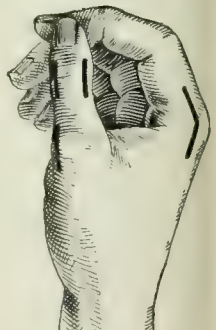

Fig. 2166.

When this is accomplished, the bones are dislocated

through the incision and are divided with the saw or by the rongeur forceps. In some instances the Gigli saw can be used without dislocation of the bone. If the operation has been a subcapsuloperiosteal one, no sutures in the bones are needed, provided a near-throsis is attempted. If not, and a pseudarthrosis is desired, a retention bone suture is used, with a small interval between the fragments. When ankylosis is desired, the bones are held in apposition by the bone sutures.

Excision of the Metacarpals.—Excision of any of the metacarpals, partial or complete, may be accomplished through a single dorsal incision. Due care must be taken to preserve unopened, if possible, the extensor tendon sheaths. The periosteum and the superficial layer of the cortex should be raised by a sharp rugine. Particular care with the metacarpal of the thumb is required in order to save the muscle attachments. The necessity for bone graft may be avoided by means of careful splinting.

Excision of the Wrist.—The history of this operation dates back as far as 1750, when Cooper, of Bungay, removed the lower end of the radius and ulna for injury. In 1762 Bagieu excised the joint for a gunshot wound. In 1794 Moreau excised the joint for disease. Lister in 1865, Boeckel in 1867, Langenbeck in 1874, and others gave a great incentive to this operation by admirable papers; yet in spite of these papers the operation has never been a popular one. Its unpopularity was not due to its mortality, for this, according to Culbertson, amounts only to from 1 to 1.73 per cent. for all cases, and, according to Gurlt's "Military Surgery," to 16 per cent. It was due to the failure to arrest the disease or because of the utter worthlessness of the hand after recovery. At the present time, with an improved technique and the aseptic treatment, these bad effects are to an extent avoided, and as a result the operation is again being strongly advocated.

Anatomy of the Wrist (Fig. 2167).—The anterior or palmar surface of the wrist is so well covered with tendons, arteries, and nerves that an approach from this side is not feasible. Upon the dorsal or lateral surfaces the bones are more easily exposed. Upon the back one can enter between the tendons without coming in contact with arteries, unless upon the external and posterior surfaces of the trapezium. The usual places selected are those between the extensor indicis and the extensor longus pollicis upon the outer side, and between the extensor carpi ulnaris and extensor minimi digiti upon the inner. In the former one encounters only the extensor carpi radialis brevior before entering the joint. None of the tendons to the fingers passing over the dorsum of the wrist is attached to the wrist, so that they can be easily retracted to either side without injury. Upon the outer side of the dorsum the extensor carpi radialis longior and brevior and, on the palmar surface, the flexor carpi radialis are intimately connected with the joint and bones to be removed. Upon the inner side the extensor and flexor carpi ulnaris are inserted into the base of the fifth metacarpal bone, and are intimately associated with the capsule and ligaments.

The bone which plays the most important part in this operation is the trapezium, which conceals and retains upon its anterior surface the flexor carpi radialis, and is covered by the radial artery upon its dorsal surface. From its crest it gives origin to the annular ligament, and by its articulation with the metacarpal bone of the thumb it becomes very necessary for the function of the thumb.

Provided the tendons are not incised, any incision which will enter the joint upon the dorsum, either to the inner or to the outer side of the mass of tendons made up of the extensor communis digitorum, extensor longus pollicis and extensor minimi digiti, will be found sufficient.

The bones of the carpus are united by a transverse ligament, of which the anterior is the [illegible]. The carpus itself may be regarded as [illegible] bone, articulating above and below with the bones of the forearm and those of the hand respectively. The lower epiphyses of the radius and ulna unite at twenty years of age. The radial epiphysis [illegible] within the joint. The ulnar epiphysis [illegible] as high as the top of the radioulnar articulation.

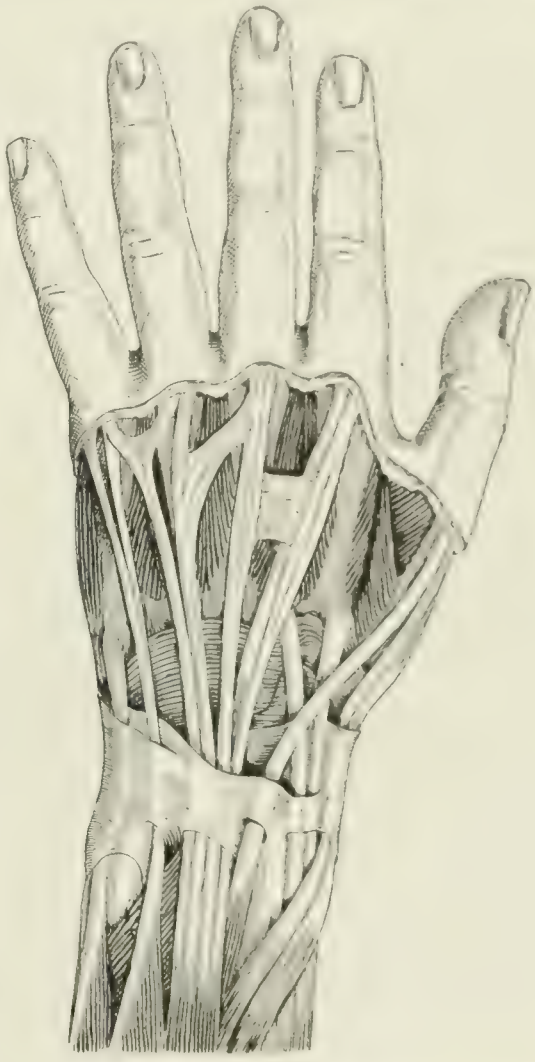

Fig. 2167

A total excision of this joint includes the removal of the articular ends of the bones of the forearm and those of the metacarpal bones besides the bones of the wrist. Any excision short of this is a partial one.

It might be noted in passing that partial excisions of this joint often result brilliantly, provided always that strict subperiosteal methods are observed and the anatomy of the extraneous parts are disturbed as little as possible.

Indications. In both civil and military practice partial rather than complete excisions are indicated. This holds good in most gunshot wounds, and in certain compound and complicated fractures and dislocations. In the civil practice of to-day the most frequent wrist injury demanding partial excision is

fracture-luxation of the carpus, of which the scaphoid fracture and semilunar luxation are the commonest. If reduction is not possible by closed or open methods, excision is the only course. For tuberculosis, chronic suppurative arthritis, syphilitic arthritis, excision is indicated after medicinal and expectant treatment fails. Such is the case in other forms of joint disease where excision, partial or complete, is used to relieve deformity or increase motion.

Excision, especially the complete, is not permissible before the fifth year of life. It is rarely demanded before puberty. When it is demanded, the epiphyses of the bones of the forearm are not interfered with, and the operation is an informal or incomplete one. The object is to remove the diseased tissue and nothing else. After puberty the operation has its best results, and it is here that complete excisions are made with good chances for functional results.

When, in an adult, tuberculosis exists in the carpus, with tuberculosis elsewhere in the body, the question to be decided is between amputation and complete excision. The general rule is that amputation should be selected if the local process succeeds the pulmonary, and that excision should be preferred if the local antedates the pulmonary. This must be taken with reserve, however, as many such cases of primary wrist involvement do best with amputation. The older the subject the more we must consider amputation in preference to excision.

Methods of incision for entering this joint are:

1. The radiodorsal incision, which, commencing at the center of the ulnar border of the metacarpal bone of the index finger, is carried upward to the middle of the dorsal surface of the radial epiphysis between the tendon of the extensor indicis and that of the extensor carpi radialis brevior, and thence between the tendons of the extensor indicis and the extensor longus pollicis. The length of this incision varies between eight and twelve centimeters, of which one-third should be above the articulation.

2. The dorsoulnar incision. In abduction and slight flexion an incision of seven to eight centimeters is made from the upper third of the fifth metacarpal over the ulna and vertically upward. In the lower part the incision passes between the tendons of the extensor carpi ulnaris and the extensor minimi digiti; over the ulna it passes in the interstice between the extensor carpi ulnaris and the extensor indicis muscles.

3. Both radial and ulnar incisions. Both are upon the dorsum (Ollier). One is dorsoradial and the other dorso-ulnar (Lister).

4. Median dorsal incision (Mayo Robson). Single ulnar lateral incision (Heron Watson).

Where two dorsal incisions are used: The radial commences opposite the center of the shaft of the second metacarpal bone, and is continued upward along the extensor indicis tendon until it meets a line joining the two styloid processes. From this point it passes upward in the axis of the forearm. The ulnar incision extends from the center of the fifth metacarpal bone along the radial side of the extensor carpi ulnaris and the ulnar side of the extensor minimi digiti until it reaches the ulna. From this point it passes between the muscular bellies of the extensor carpi ulnaris and the extensor indicis. One-third of both incisions is above the radiocarpal articulation; two-thirds are below it.

Where one dorsal and one lateral incision are used: The radiodorsal commences at the middle of the dorsal aspect of the radius at the level of the styloid process, and is carried toward the inner aspect of the metacarpophalangeal joint of the thumb, running parallel to the tendons of the extensor longus pollicis. When the radial border of the second metacarpal bone is reached, the incision is carried along this border for one-half its length. The ulnar incision commences five centimeters above the extremity of the ulna, and passes behind but parallel to the flexor carpi ulnaris as far as the middle of the fifth metacarpal bone.

Which of these incisions is the best depends largely upon the position of the fistulæ or the degree of development of the disease. Where the disease is mainly upon the ulnar side, Kocher's incision is the best to commence with (Fig. 2168); if the disease is upon the radial side, Langenbeck's incision (Fig. 2169). If the disease is extensive and requires a complete arthrectomy, no method makes so perfect an exposure as the Ollier, *i.e.* the two dorsal incisions.

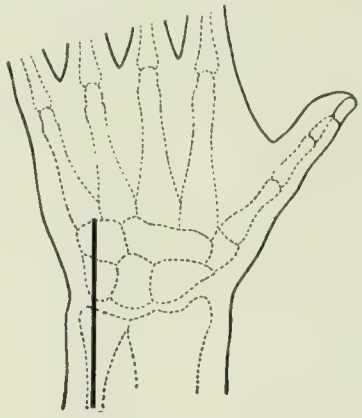

Fig. 2168.—Kocher's Incision.

We will therefore describe first the Langenbeck and then the Kocher method, and will expect the reader, from these two descriptions, to imagine that of the double dorsal incisions.

Method by the radiodorsal incision (Boeckel-Langenbeck): An Esmarch bandage is applied. The hand and wrist are placed upon a cushion with the thumb abducted and extended. The radiocarpal interspace is noted by the position of the styloid processes. The tendons of the extensor indicis and the extensor longus pollicis are also seen. The incision usually begins above the wrist between these tendons

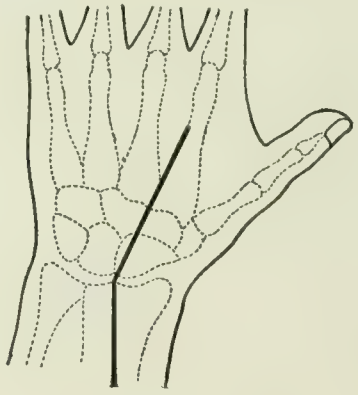

Fig. 2169.—Langenbeck's Incision.

and descends along the tendon of the index finger to the middle of the second metacarpal bone. One-third of this incision is above the radiocarpal articulation; two-thirds are below it. This incision is made through the skin and exposes the cutaneous terminal branches of the radial nerve, which are often cut. The external border of the tendon of the extensor indicis is recognized and is retracted with the inner flap out of the way. Incise toward the capsule of the wrist-joint and recognize the tendons of the extensor carpi radialis brevior attached to the third

metacarpal bone. Above the joint carry the incision between the tendons of the extensor longus pollicis and the extensor indicis, separating them without entering their sheaths. The periosteum of the radius is now incised and the capsule of the wrist-joint is divided along the inner side of the extensor longus pollicis. Avoid cutting the tendons of the radiocarpal extensors. With the sharp rugine (curved or straight), the periosteum of the radius and the capsular fibers of the wrist-joint (including the radiocarpal extensors) are respectively separated from the outer half of the posterior surface of the radius and from the bases of the second and third metacarpal bones.

The capsule is now retracted outward and the scaphoid and trapezoid are separated from their attachments to the capsule on their posterior surfaces. The trapezium is not detached until a later stage. The capsule is now retracted inward and the periosteum and capsule are separated from the inner half of the posterior surface of the radius, the triangular cartilage, and the posterior surface of the ulna. It is detached also from the posterior surfaces of the semilunar, cuneiform, os magnum, unciform, and the bases of the remaining metacarpal bones.

If the soft parts are not extensively infiltrated and the movements of flexion and extension can be made, the radius and ulna may be luxated and sawn at this time and before the carpal bones are removed.

If this can be done, the hand is flexed and pronated and the external flap is retracted. The rugine now separates the periosteum upon the anterior surface of the radius. The hand is now flexed and supinated and the remaining portion of the radius and the ulna are denuded upon their anterior surfaces. The hand is now forcibly flexed, the flaps are retracted, and the radius and ulna project through the wound. These can then be sawn transversely. This section should be as narrow as possible, usually within two centimeters of the cartilage (Fig. 2170). A retractor is now placed in the external wound, the wrist is flexed,

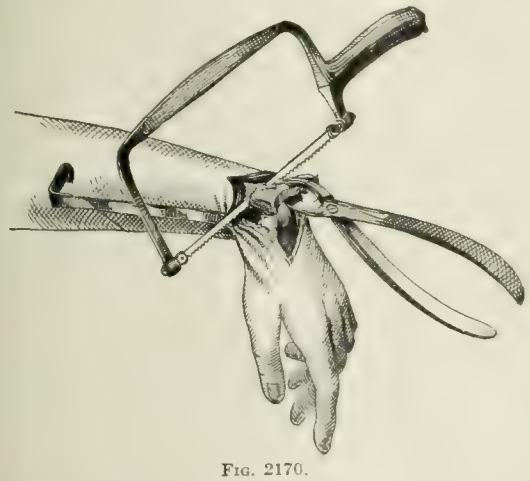

Fig. 2170.

the scaphoid bone is seized with the forceps, and its anterior and external surfaces are freed from the periosteum and ligaments.

The bone is next separated from the semilunar and is torn away easily. The internal flap is then retracted to the inner side and the semilunar and cuneiform bones are separated and removed in the same way, leaving the pisiform. The os magnum is now seized with the forceps, its anterior surface is denuded with the rugine, and its connections with the unciform, trapezoid, and metacarpal bones are severed. The trapezoid is finally removed in the same manner.

With more extensive wound retraction, the unciform may be seized and its anterior surface denuded until the base of its process is reached. This is now separated with the cutting forceps and [illegible] of the bone upon its internal surface [illegible]

If the trapezium is to be removed, [illegible] draws outward the external flap, the left hand [illegible] the thumb, and the rugine clears the posterior and then the anterior surfaces of [illegible]. The trapezium is now seized with the bone forceps, its external border is denuded, and the bone is removed.

Fig. 2171.

Provided the pisiform and the hook of the unciform are to remain, and provided also the synovial membrane has been removed, the Esmarch bandage should be loosened and the larger arteries tied. In many instances, where one is certain of not injuring the larger vessels, the bandage is not removed until after the first part of the permanent dressing is applied.

Sutures between the ends of the bones should always be used, because a mobile pseudarthrosis with mobility of the fingers is the best obtainable result. Two chromicized catgut sutures are inserted, bringing the bones within one-fourth to one-half inch, or 0.6 to 1.25 centimeters, of one another. If the tendons of the extensor longus pollicis or the extensor carpi radialis longior and brevior have been divided, they are to be carefully resutured or reinserted if separated from their insertions. The capsule is sutured with catgut. The fascia is sutured with silk or catgut. Silk or silkworm gut is employed for the skin. No drainage is used except that which occurs at the lower portion of the wound, near the index finger, where the skin and capsule are not sutured in order that any undue tension in the wound may be relieved. If the process is infective, drainage is employed through the incision by rubber tubing.

The method by the dorsoulnar incision (Kocher): The disadvantage of the preceding method, in Kocher's opinion, is the necessary separation of the radiocarpal extensors and the imperfect dorsal flexion, and possibly the volar subluxation resulting. The advantages of the dorsoulnar incision are seen in the less important action of the extensor carpi ulnaris as a dorsal flexor and its greater importance as an adductor. Hence when it is separated its loss of action is favorable to the better position and [illegible] of the hand. Though the extensor tendon of the little finger is liable to be negative in action, this danger is not so great nor is its loss of function so important as that of the extensor longus pollicis in the preceding method. Hence he selects an ulnar and [illegible] incision.

The incision is made as described above. It avoids the dorsal cutaneous branch of the ulnar nerve. The

fascia and the dorsal annular ligament are divided and the sheath of the extensor minimi digiti is incised. This tendon is drawn outward, and, following its ulnar border, the capsule of the joint is divided, and with the insertion of the extensor carpi ulnaris it is loosened from the base of the fifth metacarpal bone. Along this latter tendon the incision is carried upward upon the ulna in the interstice between the extensor carpi ulnaris and the extensor indicis. The tendon of the extensor carpi ulnaris is now retracted inward and the capsule surrounding the ulna is separated by the rugine subcapsulo-periosteally, if possible and if indicated; but, if not indicated, it should be divided by the knife, which should sever the attachments of the capsule to the ulna and to the base of the fifth metacarpal bone, leaving the flexor carpi ulnaris attached. The joint is now entered and the articulation of the pisiform and cuneiform and the process of the unciform come into view.

The tendons upon the volar surface are retracted and the attachments of the capsule to the fifth, fourth, and third metacarpal bones are divided. The attachment of the flexor carpi radialis to the base of the second metacarpal bones is preserved. In like manner the attachment of the capsule to the radius is separated.

Upon the dorsum, the extensors of the fingers are easily exposed and the capsule beneath the radiocarpal extensors and the extensors of the thumb is loosened from the radius. The two radiocarpal extensors attached to the bases of the second and third metacarpal bones are not separated from their insertions.

The hand is now carried outward and in slight flexion until the thumb touches the radial side of the forearm. The lower ends of the radius and ulna appear in the wound to the inner side, while externally is seen the first row of carpal bones (Fig. 2171). The removal of the carpal bones and a removal of thin sections from the radius and ulna and metacarpal bones are now easily carried out. It is only in the region of the trapezium and the trapezoid that the field is restricted when the bones of the forearm and the third metacarpal bones are being removed. When the bones have been removed and the capsule extirpated, the bones of the forearm and the metacarpal bones are placed in apposition, if a nearthrosis is wished. If a pseudarthrosis is desired, the bones are held in apposition more or less closely by chromic-acid catgut. The capsule and skin are now sutured. Drainage in aseptic cases is secured by leaving a small portion (one to two centimeters) of the incision open; or, if the wound be septic or hemorrhage be imperfectly stopped, by rubber tubing or rubber-tissue strips through some portion of the incision.

When the disease is upon the radial side of the carpal or metacarpal bones, or when the radial side of the joint is exclusively the seat of the disease, the radiodorsal incision is the incision of choice. When the disease is confined to the ulnar side or the joint as a whole is involved but not greatly infiltrated and swollen, the dorso-ulnar incision is the incision to be selected. When the whole joint is involved and the tissues are greatly infiltrated in front and behind the joint, both dorsal incisions are preferable to either singly. Hence we would select for these cases the incisions recommended by Ollier. These incisions are the same as those already mentioned as Langenbeck's and Kocher's. The direction of the skin incision varies somewhat, but the route to the joint is between the same structures.

Excellent results have been obtained by Drs. Mynter and Taylor by means of a method suggested by Professor Stuckgaard, of Copenhagen, in 1891. This method consists in splitting the hand between the second and third fingers. The incision is both palmar and dorsal. The incision upon the dorsum begins at the radius and extends to the interdigital fold between the second and third fingers. The palmar incision extends from the interdigital fold not farther than the superficial palmar arch. The dorsal incision divides the skin and the subcutaneous tissue, but no tendons. It avoids, in passing between the metacarpals, the annular volar ligaments, the flexor tendons and the superficial arterial arch. The wrist is now split between the trapezoid and os magnum in the second row and between the scaphoid and semilunar in the first row. Retraction of each side now allows of a complete exposure of the wrist-joint.

No matter which method of excision may be chosen, (1) the trapezium should be saved if possible, so that the motions in the carpometacarpal joint of the thumb may be preserved; (2) the unciform process of the unciform and the pisiform should also be preserved, if possible, on account of important muscular attachments; (3) the section of the bones of the forearm should be made within two centimeters of their articular cartilages; (4) in so far as is feasible the operation should be a subperiosteocapsular one.

The After-treatment.—The limb is to be placed upon a properly padded splint in such a manner that the hand shall be sustained in the position of dorsal flexion. (Fig. 2172.) These splints fix the wrist-joint but allow

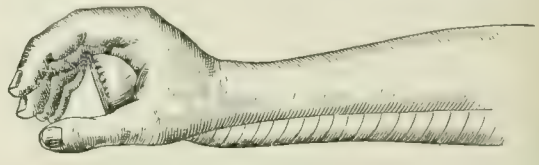

Fig. 2172.

passive motion of the fingers. They pass from above the elbow to the fingers and thumb. The latter pass beyond the splint and can be easily grasped for passive motion. Where the wounds are aseptic and no drainage is required, as in a case of simple injury, the wound usually heals in from ten days to two weeks. Where the operation is done for disease, the cavity is often packed with gauze, and, as it may require two or three scrapings with the curette, the healing of the wound may be delayed for from four to six weeks. As soon, however, as the tissues are solid, though the splint is to be continued for a long period to prevent palmar dislocation and adduction, passive motion at the wrist must be assiduously practised if we desire a nearthrosis or a mobile pseudarthrosis. If we desire an ankylosis at the wrist, passive motion must be interdicted. Passive and active motion of the fingers is practised as early as possible, in some instances at the third to fifth day after operation. After removal of the splint, a prosthetic apparatus must be worn. This apparatus should allow flexion and extension at the wrist if desired. From this time on, the patient's aim must be to increase the range of motion in his fingers and in the wrist. Much depends upon his own exertions in securing a good result.

The functional results after this operation vary. Culbertson, in 58 cases of gunshot wounds, reports the following results: Good, 1.7 per cent.; indifferent, 27.5 per cent.; bad, 13.7 per cent.; amputated, 3.4 per cent.; not stated, 53.4 per cent. In 14 cases of injury the results were as follows: Good, 28.5 per cent.; indifferent, 57+ per cent.; not stated, 14+ per cent. In 79 cases in which excision was performed for disease the results were: Good, 7.5 per cent.; indifferent, 45.5 per cent.; bad, 13.9 per cent.; amputated, 12.6 per cent.; not stated, 20.2 per cent. In our own civil war ("Med. and Surgical History of the War of the Rebellion," part ii., vol. ii., Otis), 6 cases of complete excision gave an indifferent result in 83.3 per cent.; amputation and death in 16.6 per cent. Gurlt's statistics of military surgery gave ideal results in 6.25 per cent.; good results in 50 per cent.; indifferent

results in 37.5 per cent.; bad results in 6.25 per cent. Nepveu[4] gives a collection of 36 cases. The results were satisfactory in 41.6 per cent.; indifferent in 36.1 per cent.; bad in 22.2 per cent. Ollier[5] believes, and has shown in two cases following a traumatism (partial excision), that ideal results may be obtained by carefully performed operations and long-continued after-treatment. The mortality statistics are about ten per cent. for all cases. For gunshot wounds the mortality is about fifteen per cent. For disease, a death following operation is a rarity.

Excision of the Radius and Ulna.—Excision of either of the bones of the forearm may be indicated after extensive injury, and in the presence of a sequestrum or neoplasm involving most of the shaft of the bone. Except in the very young, in whom preservation of the epiphyses and of the periosteum offers a chance of total reformation, the ultimate result must be great deformity from inclination of the hand to one or other side with subsequent, though not necessarily complete, impairment of function. In adults the resources of surgery at the present time offer nothing to replace the bone that has been removed. Despite this, and where the circumstances of the patient permit, the preservation of the hand with *one* bone, when aided by an orthopedic appliance, may furnish more function than an artificial limb, and if a trial of such a course prove disappointing, the forearm may still be removed at or near the elbow. Not often, however, will *total removal* of the bone, as implied in the term *excision*, be indicated.

Resection, or the removal of *part* of the bone, on the other hand, is much more frequently performed. In his "Observations in Clinical Surgery," Syme, in 1862, thus employed resection for ununited fracture of the humerus, irremediable by other methods, and described resection as "cutting off the broken ends of the bone, together with the ligamentous substance connecting them, so as to obtain two osseous surfaces which may be placed in proper relation to each other." No deformity need follow resection in these days, when any portion of the length of the shaft may be almost perfectly reproduced by the insertion of an intramedullary bone splint which, in case one end of the bone has been removed, need but contact with the remaining end, regardless, almost, of how small the latter is. In the forearm, as in the leg, there is the natural advantage of the presence of two bones, whose mutual relationship is such that when one is injured or diseased its sturdier fellow supports it and maintains the length of the limb until it is able to resume its own function.

The incision for the *radius* is best made upon its posteroexternal aspect, along the intermuscular interspace between the brachioradialis externally and the the extensor carpi radialis longus internally. (Fig. 2173.) Here the bone is most subcutaneous, and least in relation with important vessels or nerves, except just below the neck, where the posterior interosseous division of the musculospiral nerve winds around it externally from the anterior to reach the posterior surface. The other division—the radial nerve—lies to the radial side of the radial artery, under shelter of the brachioradialis muscle, whose tendon it crosses five centimeters above the snuffbox to reach the dorsum of the hand. Being a purely cutaneous nerve with a limited and not extremely important distribution, its division is of minor consequence. Having cut down to the bone, and working subperiosteally with the sharp rugine, when the insertion of the pronator teres muscle is encountered on the outer aspect of the middle of the shaft, it is displaced inward, onto the anterior surface. The supinator muscle, wrapped around the upper third of the shaft, is divided in the line of the incision, the anterior portion with the radial nerve pushed inward onto the anterior surface, and the posterior portion with the interosseous nerve pushed inward onto the posterior surface. The bone is now divided at its center and each half is freed to and into the wound and removed. The bed of the bone is then closed by suturing the periosteum, which bears the [illegible] the joints and the muscular attachments about the shaft, and then the divided [illegible] fascia, the superficial fascia and the skin. [illegible] drainage is provided, and the forearm is [illegible] by a long, straight splint. Restoration of the function of the elbow and the wrist-joints is insured by the institution of a graded course of passive motion within a few days of the operation.

Fig. 2173.

Resection of the radius is performed through an incision which is similarly located, but whose length is adapted to the extent of the bone to be removed.

The incision for the *ulna* is made along its subcutaneous posterior border, and falls in the interval between the anconeus and the flexor carpi ulnaris muscles above, and the flexor and the extensor carpi ulnaris below. (Fig. 2173.) The position of the posterior branch of the ulnar nerve beneath the flexor carpi ulnaris, and about five centimeters above the wrist-joint, should be borne in mind, although, being purely cutaneous in distribution, its division is of no great significance. Working downward through the intermuscular interspaces, the periosteum is incised through the entire length of the incision and, at the center of the shaft of the bone, is cleared from the circumference, and the bone sawn through. Each half is then enucleated from the periosteal and, at the extremity, from the capsular envelope. The remaining steps are similar to those described for excision of the radius.

Fortunately, excision (total removal) of the ulna is seldom necessary. Ashhurst[6] mentions five surgeons who have performed this operation. The stability of the elbow-joint is insured by the grasp of the greater sigmoid cavity of the ulna upon the internal condyle of the humerus, and the preservation of this relation, which is attained in resection (partial removal) of the bone at any point below the base of the coronoid process, is a desideratum much to be striven for, since a bone-graft may be inserted into the stump with a good prospect of the entire bone being reproduced. The wobbly condition of the elbow-joint after excision of the ulna may well be imagined, although much stability may be imparted by a well-devised orthopedic apparatus.

Excision of the Elbow-Joint. [illegible] in 1758 or 1759, Filkin in 1762, and Justamond in 1783 excised portions of this joint for injury or disease, but the first methodical operation is ascribed to Moreau in 1794. This method was enthusiastically accepted in England by Syme, and has since been established by numerous surgeons both in civil and in military practice. Excision of the elbow consists in removing the inferior extremity of the humerus and the upper extremities of the radius and ulna. In all

cases the insertions of the brachialis anticus and of the biceps must be preserved, or if detached they must be replaced in order to insure the function of the joint.

Usually less than two centimeters should be removed from the radius and ulna. More can be removed from the humerus without destroying its function. Usually the line of section is at the upper border of the epitrochlea, *i.e.* the section is made well above the articular surface (Ollier, "Traité des Resections," t. ii., p. 203). When more is removed than is here recommended, one must expect a flail joint, unless special precautions against it are taken. When the section is below the epitrochlea—*i.e.* just above the articular cartilage—one can expect a nearthrosis, a pseudarthrosis, or an ankylosis. If ankylosis results, the bones must be placed at a right angle with the radius in semipronation. This will give a very useful and serviceable extremity. If a nearthrosis follows, then the following condition most frequently occurs: The bones become fashioned so as to fit one another. They become smooth, polished, and shaped so as to allow flexion and extension. The lateral ligaments prevent any lateral displacement at the new articulation, and the movements of supination and pronation, though limited, are sufficiently supplemented by rotation at the shoulder-joint. The movement of the elbow, hand, and fingers is sufficiently strong for all ordinary work. Such a condition is the best result attainable, and should be considered ideal. If pseudarthrosis exists, the union of the bones is by means of connective tissue. Such a union, if the bond is not too long, gives a good result. Where the union is short and where no lateral displacement at the point of union occurs, if the muscular power is sufficient, quite as useful a limb can be obtained as by the development of a nearthrosis.

The Indications.—For *gunshot injuries* in young and healthy persons in whom the articular cartilages are intact and in whom the tissues about the joint are not extensively damaged, the conservative treatment or, at the most, restricted operation should be employed.

In *severe* bone injuries of the elbow-joint, including the articular cartilages with slight or no injury to the vessels and nerves, a partial or a complete excision is indicated, provided the age of the patient or his general condition does not demand an immediate amputation.

In *severe injuries* of the articular cartilages and of the bones, with severe injury to the vessels and nerves, amputation is required, especially in the aged.

In old *injuries* to the joint, resulting in ankylosis or pressure upon the main vessels or nerve trunks, a complete rather than a partial excision is indicated, because the tendency to secondary ankylosis is great by reason of the marked reparative power in all the tissues set up by previous injury. In old dislocations it is good practice to reduce the dislocation by operative means, unless the contracture of the soft tissues demands an excision rather than a reduction. The earlier the dislocation comes into the surgeon's hands the more successful will be the reduction by operative interference.

Ankylosis in a faulty position, resulting from injury or disease, is curable by complete excision only when the age of the patient (from twenty to thirty-five), the condition of the muscles, the presence of cicatricial bands about the joint, or the new bone production in and around the joint, will not interfere with the after-result. In cases in which these conditions exist and the tendency to new bone production is a marked one, a partial operation with a correction of the faulty position is alone indicated. Selected cases of elbow ankylosis, if non-tuberculous, or if due to other infections after the active process has passed, may present favorable material for the interposition fascia-fat flap operation of Murphy. Good functional results may be obtained but it must be borne in mind that Dr. Murphy himself regards the elbow-joint as less favorable than the shoulder or hip-joints for his method.

Tuberculosis.—After conservative treatment has failed, a complete excision is usually indicated, but during the first three or four years of life it is not recommended. At this time curetting is sufficient. After three years, do a partial operation, if possible, or a complete one if necessary. In either case, however, we must remove the disease. Excision is indicated in some cases of *suppurative arthritis* (chronic), in *arthritis deformans* in a single joint, and in *tumors* involving the bones of the joint (exostoses).

It must be remembered that only one-tenth of the total growth of the arm and forearm is contributed by the epiphysis at the elbow (Ollier), so that earlier excisions may be attempted here than elsewhere. In general we say that in injury and gunshot wounds, partial rather than complete operations are indicated. For disease, complete rather than partial operations are indicated. For ankylosis, complete rather than partial operations are indicated. In youth much can be expected in the production of pseudo- or nearthroses. In the adult, unless some chronic irritation (inflammation) is present or the amount removed is small, the joint is liable to be a flail one.

Anatomy.—The elbow is a pure hinge-joint. The reëstablishment of its function demands that the bones be so shaped as to flex and extend easily while in contact, that the lateral ligament holding the joint be short and not yielding, and that the attachment of the muscles which move the joint in flexion and extension, as well as in supination and pronation, be preserved.

As the anterior portion of this joint is not used for entrance into the joint, we will consider only its lateral and posterior aspects.

The posterior branch of the radial nerve, which is a motor nerve for the extension of the hand and fingers and for extension and abduction of the thumb, enters the supinator muscle about two centimeters below the articular surface of the head of the radius and passes obliquely through its fibers around the radius until it emerges three to four centimeters below the interarticular line in the posterior interosseous space. Upon the inner side the ulnar nerve passes behind the internal epicondyle between the extensor carpi ulnaris and the periosteum covering the internal surface of the ulnar. These two nerves are to be avoided. Both the brachialis anticus and the biceps are attached at points sufficiently removed to be saved in the more typical and complete operations. The brachioradialis, because of its attachment to the external supracondylar ridge, can be preserved in its attachment even when a large extent of the humerus is removed.

The supinator, is rarely injured because of its ready separation from the humerus with the periosteum. Such is the case with the muscles attached to the internal and external epicondyles of the humerus, which can with care always be separated from the bone and kept in relation with the periosteum of the humerus and the fascia forming the intermuscular septa, and the lateral ligaments of the joint. The triceps, however, is an important muscle. The major part of its tendon is inserted into the olecranon process of the ulna. It has, however, lateral attachments connecting it with the deep fascia of the posterior surface of the forearm. Of these connections, that with the fascia covering the anconeus and the posterior surface of the forearm is very strong, while that with the fascia covering the internal surface is thin and not strong. It is necessary, therefore, to maintain this connection with the deep fascia of the forearm when the attachment to the olecranon is removed, if we wish to obtain after excision the full power of extension.

The arterial supply of this joint is carried on by the circle formed by the radial and ulnar recurrents, the

interosseous recurrent, and the anastomotica magna. These may be avoided by the subperiosteal method.

The interarticular line of the elbow-joint is represented by the middle third of a line joining the tips of the two epicondyles.

The humeroradial articulation is represented by a horizontal line; the humero-ulnar, by an oblique line, passing from without inward and above downward.

The external condyle of the humerus is less than two centimeters above the articular line. The internal condlye is more than two and one-half centimeters above it.

The lower epiphysis of the humerus joins the shaft at the seventeenth or eighteenth year.

The epiphysis of the radius joins the shaft at the sixteenth or seventeenth year.

The epiphysis of the ulna (olecranon) joins the shaft at the seventeenth year.

These epiphyseal cartilages have finished their growth by the seventeenth year, and excisions of large portions may be made at this age, although the muscles mentioned as important must be preserved to obtain the best results. When they are sacrificed, prosthetic apparatus must be used to supply the deficiency.

The Methods of Incisions.

The incisions used in excisions of the elbow-joint may be divided into: (1) those which enter the joint upon the ulnar side; (2) those which enter upon the radial side; (3) those which enter upon both sides or from behind. To the first belong the incisions of

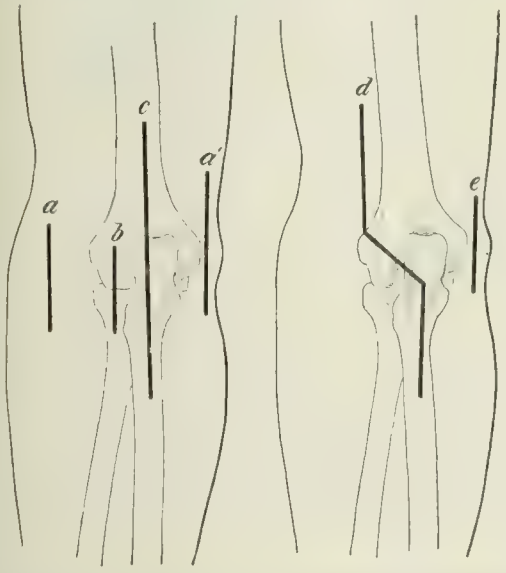

Fig. 2174.—Excision of Elbow. *a*, *a'*, Radial and ulnar incisions; *b*, incision for excision of radio-ulnar articulation; *c*, incision for Langenbeck's operation; *d*, incision for Ollier's operation; *e*, ulnar incision sometimes needed with Ollier's method.

Liston, Langenbeck, Gurlt, and Jaeger. To the second belong those of Ollier, Stimson, Roux and Nélaton, Kocher, and Cavazzani. To the last belong the H-shaped incisions of Moreau and Dupuytren, the lateral incisions of C. Hueter and of Vogt, the posterior triangular flap of Textor, and the parallel posterior incisions of Murphy.

Of all these incisions we find that four are sufficient for all excisions, complete or partial. In ankylosed joints and in old dislocations a combination of the Kocher's radial incision and the ulnar incision of C. Hueter will be found in the severer cases to be most satisfactory. In injury and in disease other than the above the Langenbeck, the Cavazzani, and the [illegible] incisions are preferred.

These latter incisions are [illegible] they do the least injury to the fibrous expansion of the triceps insertion and no injury to the [illegible] the triceps or the anconeus muscles.

The Langenbeck or dorso-internal [illegible] mended when the disease involves [illegible] internal segment of the joint.

The Kocher, or dorsoradial, incision [illegible] useful when the disease involves more [illegible] radio-humeral in addition to the humero-ulnar articulations.

The bilateral incisions above recommended are useful in old dislocations and in severe ankylosis following disease, injury, or operation.

I. *Langenbeck's Method.*—The Esmarch bandage is to be applied, if not contraindicated. The top and crest of the olecranon process having been determined, an incision is commenced four to five centimeters above the olecranon, passing through the tendon of the triceps and along the inner border of the crest of the olecranon to a point where the process disappears in the shaft of the ulna (Fig. 2175). Usually this point is four to five centimeters from the tip of the olecranon. This incision is carried down to the bones throughout. A retractor is placed in the external flap, and, with the forearm extended, a rugine or knife separates the periosteum of the olecranon and the ulna, carrying with it the insertion of the triceps, that of the anconeus and that of the supinator.

Having reached the external epicondyle, the surgeon should separate the external lateral ligament and the common origin of the extensors and supinators from the epicondyle subperiosteally or by removing with these structures a part of the epicondyle (P. Vogt). When this is sufficiently free and the humeroradial joint is exposed, the forearm may be extended to complete the subperiosteal separation upon the anterior surface of the humerus. This completed, the internal flap is detached with the periosteum, while the forearm is extended until the internal surface of the olecranon is free and the coronoid process below and the internal condyle above are fully exposed. With the retraction of the periosteum of the humerus and olecranon, the ulnar nerve and the lateral ligament [illegible] carried away and are free from all danger. When the lower part of the humerus is sufficiently free, the forearm is again flexed and the ulna and radius are separated from it. The periosteum and capsule of the joint are separated from the anterior surface of the humerus as far as is necessary. The latter is then seized with the lion-toothed forceps and the bone is sawn transversely, just above the articular cartilage or, better, in a line joining the epicondyle and upper part of the epitrochlea (Ollier[5]). The olecranon process is seized with the forceps and the periosteum and capsule are separated from the coronoid process to its base, as much of the insertion of the brachialis anticus as possible being saved. The anterior fibers of the orbicular ligament are separated with the periosteum of the ulna and are displaced [illegible] so that the head of the radius can be [illegible] shaft if desired. The olecranon and coronoid processes are now removed together from the shaft, if desired, and if thought necessary (Fig. 2176). Otherwise, if sufficient bone can be left to form a new olecranon process, the bone is sawn as in Fig. 2177. This will give a projecting portion representing the former olecranon, which is very useful in preventing forward dislocation of the ulna during the after-treatment.

After removal of the extremities of the bones the synovial membrane is dissected out completely, and such sinuses as appear are excised or curetted.

The sawn surfaces of the radius, ulna, and humerus are placed in apposition and at an angle of 135°—*i.e.* in nearly complete extension. In this position the tendency to forward dislocation of the radius and ulna through contraction of the flexors is avoided. If

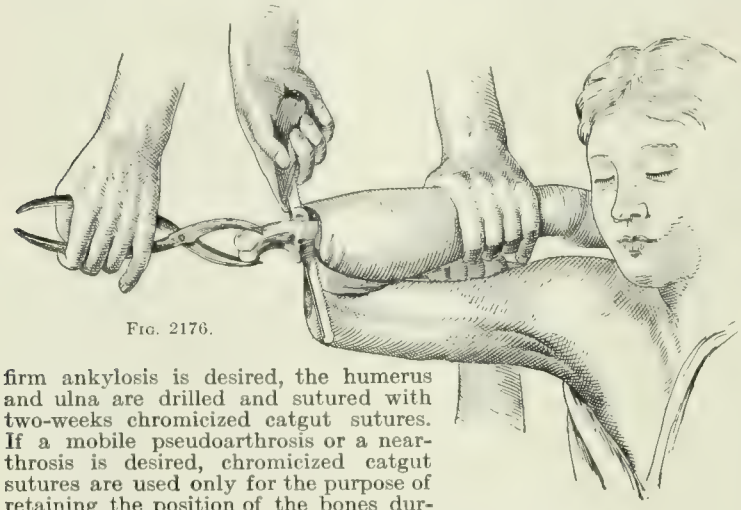

Fig. 2176.

firm ankylosis is desired, the humerus and ulna are drilled and sutured with two-weeks chromicized catgut sutures. If a mobile pseudoarthrosis or a nearthrosis is desired, chromicized catgut sutures are used only for the purpose of retaining the position of the bones during the application of the primary dressing. Such sutures should not last longer than a few days. The Esmarch bandage is removed and the larger arteries are ligated.

The capsule and the periosteum are sutured with catgut in position over the ends of the bones. The skin is sutured with silkworm gut, providing the case is an aseptic one, and a small portion of the wound (two centimeters) at its highest point is not sutured, in order that leakage of blood may take place easily during the next few hours. If one so desires, a small piece of rubber tissue may be inserted through this opening to prevent its closure. The forearm is slightly flexed and semi-pronated. It is retained in this position by a splint, either plaster-of-Paris reinforced by sterilized basswood strips or the Esmarch's wire splint (Fig. 2178). With either of these the arm and forearm are elevated and retained in this position by suspension.

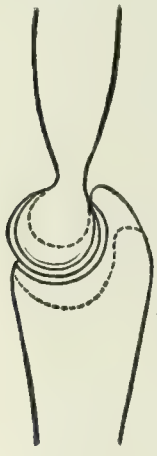

Fig. 2177

Kocher's Method.—By the Langenbeck incision, disease in the radiohumeral articulation is not so easily attacked as by the Ollier bayonet incision (Fig. 2174 *d*.). Ollier's incision, which passes in the interstice between the external head of the triceps and the anconeus, must divide the nerve supplying the anconeus, since it is a branch of the division of the musculospiral supplying this portion of the triceps. Hence Kocher planned an incision which avoids this nerve division and does not paralyze this portion of the triceps.

The forearm is flexed at an angle of 150 degrees, and a stirrup-shaped incision is made, which begins three to five centimeters above the epicondyle and over the external border of the humerus, and descends to the head of the radius. From this point it descends downward and slightly inward, following the external border of the anconeus until it reaches the ulna at a point from four to six centimeters from the tip of the olecranon. From this latter point it curves over the posterior surface of the ulna inward and upward for a distance of from one to two centimeters (Fig. 2179). This incision above the epicondyle passes in the interstice between the brachioradialis, extensor carpi radialis longus, and the common tendon for the supinators and extensors of the hand and wrist and fingers in front and the triceps and anconeus behind. From the epicondyle to the lateral surface of the ulna, the incision passes in the interstice between the anconeus and the extensor carpi ulnaris until it reaches the ulna at a point six centimeters below the tip of the olecranon. The latter part of the incision usually divides the lowest fibers of the anconeus, as they often extend a longer distance upward on the shaft of the ulna. This incision passes in the interval between those muscles innervated by the posterior muscular branch of the musculospiral and those supplied by the external muscular and posterior interosseous branches of the same nerve. The external ridge of the humerus, the epicondyle, the radiohumeral joint, and the supinator muscles are now exposed, and the capsule of the radiohumeral and humeroulnar joints are in view.

If the olecranon is diseased, the chisel may be placed upon its base and the process be removed from the shaft together with the attached triceps and anconeus muscles. This flap is retracted inward and the joint is exposed to its full extent. If the olecranon is not diseased, the periosteum beneath the external head of the triceps and the capsule are separated from the posterior surface of the humerus. In like manner the anconeus is separated from the epicondyle and the outer surface of the ulna, including with it the posterior humero-ulnar ligament. This dissection is continued over the ulna

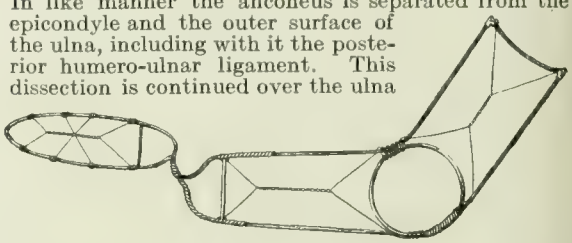

Fig. 2178.

and olecranon, separating the triceps from the olecranon and a small part of the flexor carpi ulnaris from the internal surface of the ulna. The epicondyle is now fully exposed by separating the common tendon of the supinators and extensors subperiosteally and retracting the flap inward. This exposes the external

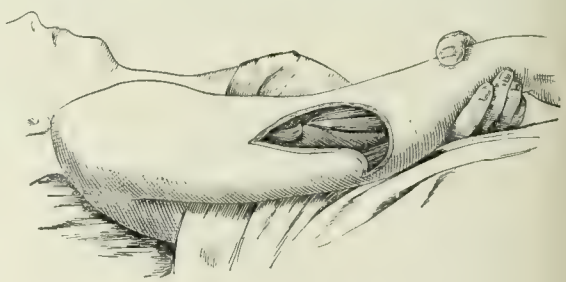

Fig. 2179.

lateral and the anterior ligaments passing from the condyle to the annular ligament of the superior radiohumeral joint. These are divided. The forearm is now extended and adducted. The joint is then brought into full view and the internal lateral ligament can be loosened from the inner surface of the

ulna and of the trochlea (Fig. 0015). With this separation, the humerus is easily cleared of all muscles anteriorly and posteriorly and the bone section made as recommended in the preceding operation.

The annular ligament is now divided and the head of the radius is removed separately from the ulna. If possible, the section of the ulna should be such as will leave a process simulating in slight degree the olecranon. Such a method is useful in preventing the anterior subluxation of the ulna. The section is the same as is shown in the former operation.

When the disease is tuberculous, it is best not to incise the synovial membrane until the dissection of the soft parts is completed and the dislocation of the radius and ulna from the humerus is ready to be made.

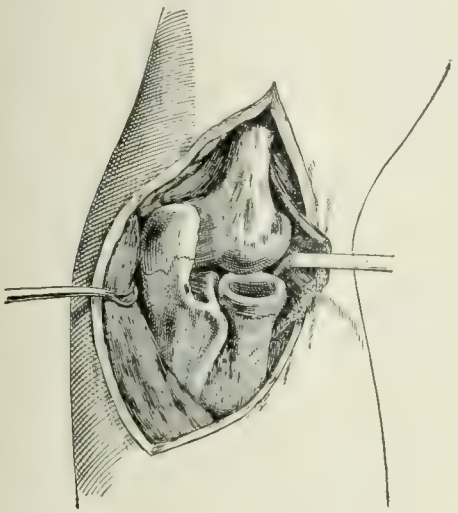

Fig. 2180.

When the synovial membrane has been completely removed and the sinuses, if any, are excised or curetted, the parts are brought into apposition and sutured. Drainage, if necessary, is made with rubber tubing or tissue at the lower angle of the wound beneath the anconeus.

Deep sutures should be sterile catgut; superficial sutures, silk or silkworm gut. If ankylosis is desired, suture the bone with two-weeks chromicized catgut. If a nearthrosis or a mobile pseudoarthrosis is desired, suture with catgut, which will last but a few days and will simply retain the bones in position during the application of the primary dressing. The extremity is placed in such a splint as has been previously recommended and is suspended and elevated.

These two methods are undoubtedly the methods of choice for both injury and disease in the vast majority of cases.

Method of Cavazzani.—There is a method very similar to Kocher's, except in the skin incision and in some of the minor details, which may be used for it in cases of exploration, partial excision, and synovial extirpation. This is the method of Cavazzani.

Three landmarks are taken—one the tendon of the biceps, one the head of the radius, and the third the olecranon process. Two centimeters below the epicondyle upon the outer border of the tendo bicipitis, an incision through the skin and subcutaneous tissue begins and passes transversely outward parallel to the interarticular line of the joint. At the outer side of the forearm it passes obliquely from below upward and ends at the inner border of the ulna near the tip of the olecranon (Fig. 2181). During the first half of this incision the forearm is extended. During the last half it is in half-flexion. This stretches the skin and prevents slipping. The upper flap is dissected up sufficiently to expose the interval between the anconeus and the [illegible] epicondyle, *i.e.*, the interstice between the [illegible] and the extensor carpi ulnaris.

The epicondyle being exposed, the [illegible] covering this interstice is divided over the neck of the radius and above the epicondyle. The epicondylar muscles are now loosened subperiosteally and are retracted inward. The capsule is thus exposed as far as the coronoid process. Upon the posterior surface the anconeus is also separated subperiosteally from the humerus and the ulna together; the tendon of the triceps is separated over the external half of the olecranon process. If one wishes to disregard the anconeus nerve supply, one may cut transversely in the interstice of the triceps and anconeus from the epicondyles to the outer surface of the ulna. The posterior capsule is now exposed. The joint is next opened by dividing the external lateral ligament from the coronoid process anteriorly to the tip of the olecranon posteriorly. A movement of adduction will now dislocate the forearm from the arm.

After the operation is finished, the forearm is replaced, the lateral ligaments are sewed, and the muscles about the epicondyle sutured in place. No vessels or nerves are injured. The radial nerve is not stretched. The tendon of the triceps is preserved in half its attachment. The epicondylar muscles are preserved. For exploration and synovial extirpation, Cavazzani's method is very satisfactory, for the reasons above stated.

For *ankylosis* and for the reduction of *old dislocations*, the method of Jeffrey (which has been more precisely described by Marangosi), those of Heuter and of J. B. Murphy are undoubtedly the best. This is especially so in fractures with dislocation, where the reduction requires the removal of the callus with or without a partial excision; in old dislocations, which require the removal of the callus and the adhesions in order to effect reduction; in all impractical ankyloses following disease, injury, or operation, which are to be made practical ankyloses or in which arthrolysis is to be attempted; and, lastly, in cases in which redislocation has followed the operative reduction of an old dislocation. With the posterior incision or the single lateral incision, one comes upon the joint at a disadvantageous side for the correction of an ankylosis or for the removal of callus.

In ankyloses it is not possible to dislocate the bones, and the removal of the necessary wedge or piece of bone must be done without displacement. For this reason, Heuter and others accepted the bilateral incisions which Jeffrey formerly used in all excisions. These incisions have been greatly modified by subsequent operators, but the method here described will be found to approach the ideal method. It consists of the radiohumeral incision of Kocher and the ulnar incision of the bilateral methods. The incision upon the radial side commences five or six centimeters above the external condyle, and penetrates between the [illegible] brachioradialis and extensor carpi radialis [illegible], until it reaches the external humeral border and descends to just behind the epicondyle. It here passes obliquely downward and inward in the interstice between the anconeus and extensor carpi ulnaris for a distance of from two to three centimeters. Unless the radius is involved, the annular ligament is avoided. Now clear the anconeus and the triceps from the capsule or tissues beneath them and retract them

inward. Clear the supinator and extensor group from the epicondyle and retract them inward.

An ulnar incision is next made upon the internal border of the epicondyle or at the place where it had been broken off or displaced. This incision is from eight to ten centimeters in length. The ulnar nerve is freed and displaced backward. The pronator and flexor groups of muscles are displaced outward and in front after being freed from the internal border of the humerus and the epicondyle. These incisions descend to the bone, and one separates subperiosteally with the rugine, or extraperiosteally with the knife, the soft parts from the bone upon both surfaces of the humerus. In the reduction of old dislocations, the method pursued must be extraperiosteal. A blunt retractor is now inserted in front of and behind the humerus, for the purpose of guarding and lifting the soft tissues from the bone. If one desires, the bone section may now be made with the saw. If it is thought better, the adhesions between the humerus, olecranon, ulna, and radius may be divided, and the humeral extremity first and the radius and ulna afterward displaced through the external incision. They may then be sawn and replaced. If the case be an old dislocation, the fibrous bands between the internal condyle and olecranon must be divided. The epicondyle, if torn off and displaced, must be loosened and returned. The trochlea of the humerus and the sigmoid cavity of the olecranon must be cleared of all fibrous or bony tissue. When this is accomplished, a movement of adduction of the forearm will expose the humeral extremity in the external wound and allow the removal of the new formation in the olecranon fossa. When this is finished the radius and ulna may be exposed in the same manner and the process of clearing their articular surfaces completed. With the completion of the work upon the bones the extremities are apposed, sutured if desired, and immobilized at an angle sufficient to prevent dislocation. In the reduction of old dislocations, this is usually a right angle, with the forearm in full pronation to prevent redislocation. In excisions in which motion is desired the position is one of nearly complete extension, with semi-pronation. In cases in which an ankylosis is desired, the forearm is left at an angle a little less than a right angle.

Dr. J. B. Murphy makes two longitudinal incisions about ten centimeters in length, one on either side of the olecranon process. The ulnar nerve is first isolated, freed from its bed, and drawn to one side. The lower end of the humerus, the internal condyle, and the surface of the ulna are exposed by detaching the muscles on the inner side. The external condyle and the head of the radius are similarly exposed and the ankylosis is loosened by means of the chisel. The quantity of bone to be cut away depends entirely upon the amount necessary to secure complete flexion and extension and the bone removed may be taken from the humerus, the tip of the olecranon, the coronoid process, or the head of the radius. Recently Dr. Murphy has been inclined to excise transversely only a small section of the articulating surface of the humerus, remove the head of the radius, and then round and shape the cut end of the humerus before proceeding with the next stage. The next step is to implant a flap taken from the external lateral aspect of the arm, base downward, or, if necessary, another flap from the internal aspect. This flap (or flaps) is taken from the deep fascia, is drawn into the joint to cover the articulating surfaces, and is sutured to the remnants of the joint capsule with chromic catgut. Care is taken to prevent the ulnar nerve getting caught in the cicatricial tissue. With the removal of all obstructions to joint motion, and the interposition of soft-tissue flaps, the wound is closed, using chromicized catgut for the deep sutures, plain catgut for the superficial sutures, and horsehair for the skin. The arm is placed in acute flexion in a plaster-of-Paris case. At the end of ten days the sutures are removed and passive exercise commenced, but the case is worn for four or five weeks.

Helferich's method, as first proposed in 1894, is followed in Bier's clinic (Reiner, *Deutsche Zeit. f. Chir.*, 1910, civ.) in ankylosis of the elbow. After the removal of all new bony growth and osteophytes the lower end of the humerus is made convex while the radius and ulna are made concave. A muscular fascial flap is taken from the radial side of the triceps, introduced into the joint, and sutured between the bones. The arm is put up in extension for eight days and then there ensue daily dressings with massage, active and passive motion, hyperemia by hot air, and at each dressing the elbow is placed at a different angle. The after-treatment is considered as important as the operation and while it is tedious and painful the results seem to justify it.

The After-treatment.—It is to be borne in mind that there is always a tendency to displacement of the fragments, that too wide a distance between the extremities of the bone tends to a flail joint, and that too close a distance tends to ankylosis. The usual distance for obtaining a false joint is between one and two centimeters. In children ankylosis is to be especially feared; consequently, as soon as possible passive motion must be enforced. Usually on the third day passive motion is begun, and is repeated daily in the wrist and fingers. On the twenty-first day the forearm is moved in flexion every second day, and returned to the original position of extension. In from four to five weeks the forearm can be easily moved to ninety degrees and returned to the original position of extension. The movements of supination and pronation are made at the same time as those of flexion and extension.

At the end of from six to eight weeks a splint can be dispensed with, when massage and electricity are used. The daily use of the arm must be secured. At four months the movement in the new joint should be sufficient to allow the patient to feed and dress himself and to carry quite heavy weights. It will require one year before one can see the best results in motion and stability.

If large quantities of bone have been removed and the operation has been subperiosteal and subcapsular, it is best to be satisfied with an ankylosis at a right angle and in semi-pronation rather than run the risk of a flail joint. If ankylosis is attempted, passive motion in the wrist, fingers, and shoulder is daily practised, in order to preserve their full power.

If the amount of bone removed has not been great, say enough to allow from one to two centimeters between the bones of the arm and forearm, and if the operation was subcapsuloperiosteal or partly so, it is best to attempt a nearthrosis or a pseudarthrosis. After the third week, when the wound is healed and passive motion at the elbow is begun, an angular hinged splint should be applied, which will prevent, during the exercises of flexion, extension, supination, and pronation, any lateral displacement of the bones. Very great care must be given by the patient and the surgeon to obtain the ideal result.

One factor must not be lost sight of during the after-treatment, and that is that an angular ankylosis with movement at the fingers, wrist, and shoulder is more useful in a laborious occupation than the excessive mobility often resulting from these excisions. Another fact to be borne in mind is that in the young motion is to be begun early. In the adult, in whom there is less danger of ankylosis than there is of a flail joint, passive motion need not be begun until some firmness is present in the joint.

The mortality, according to Culbertson, is as follows: *Gunshot wounds:* Partial excision, 27.02 per cent.; complete excision, 25.30 per cent. *Injury:* Partial excision, 7.4 per cent.; complete excision, 21.05 per cent. *Disease:* Partial excision, 11.11 per cent.; complete, 9.94 per cent.

In the Franco-German war (1870–71), excisions for gunshot injuries gave a mortality of 27.41 per cent. (Gurlt). In our own civil war, gunshot injuries, when excised, gave a mortality of 23.70 per cent. Salzman, quoted by Ollier, gives the mortality of excisions for ankylosis as 1.47 per cent. Functional results are in the main good, especially in civil practice.

For disease, Culbertson gives 6 perfect and 32 useful joints in 40 cases of partial excision, and 32 perfect and 196 useful joints in 290 complete excisions. Gurlt's statistics, obtained from the German wars (1848–77), gives 5.63 per cent. as very good, 23.66 per cent. as good, 53.24 per cent. as moderate, 14.37 per cent. as bad, 3.09 per cent. as very bad. Nepveu[9] presents twenty-one cases with extensive restoration of the parts. The general form of restoration is brought about by the osteophytic growth of the condyles of the humerus.

In Kocher's clinik, 1872–97 (Oschmann[10]), where a large number of good functionating joints were obtained, it was noticed that rotation at this joint was better then flexion and extension. It was observed that much value is to be placed upon the preservation of the anconeus for obtaining full power in extension of the forearm. It was also observed in three cases that repeated excisions were necessary to secure good function. Hence the importance of a thorough removal at the first operation is plainly seen in these cases. After healing had taken place, the most frequent impediment to flexion seemed to be enlargement of the internal condyle or of the coronoid process. For these cases secondary excisions, removing the impediment to motion, are properly indicated.

The functional results of excision for old, unreduced dislocations show that 70 per cent. have good results, 30 per cent. have bad (Cuhorst), while the bloody reposition of these old dislocations gave 76.9 per cent. of excellent results, with 23 per cent. of bad results, none of which can be considered due to the method of operation.

Excision of the Superior Radioulnar Articulation.—This operation (Fig. 2174, *b*) is occasionally made use of in old dislocations, in fracture of the head of the radius impeding the motions of rotation, of flexion, or of extension.

Operation.—An incision of from five to seven centimeters is made in the same manner as the Kocher incision for the excision of the elbow-joint. This incision passes in the interval between the anconeus posterointernally and the extensor carpi ulnaris anteroexternally. After their attachments to the epicondyle have been loosened, the tissues are retracted and the capsule is exposed. This is incised and the head of the bone is removed as close to the shaft as possible. The section should be at the point where the annular ligament is closely applied to the neck of the radius. With this incision there is no danger to the musculospiral nerve anteriorly. The posterior interosseous nerve, as it crosses within the fibers of the supinator muscle, is distant from the epicondyle of the humerus four centimeters on the external surface of the forearm. On the posterior surface, where it meets the interosseous artery in the interval between the supinator and the extensor ossis metacarpi pollicis, the distance from the epicondyle is usually six centimeters or over. Hence it is difficult to injure it unless the incisions are prolonged further than recommended. After the head is removed, the capsule and ligaments are sutured and a nearthrosis or pseudoarthrosis is attempted. A strip of fascia may be interposed with advantage.

At ten or fourteen days passive motion is begun and continued for several weeks. It usually requires three months to obtain the best results. In three cases of fracture of the head of the radius with abolition of supination and pronation in marked degree observed by Hartley, [illegible] of the [illegible] conservative after-treatment gave [illegible]

Excision of the Humerus.—In [illegible] removal) of the humerus [illegible] tage of having a companion bone to [illegible] as exists in the forearm, is present. [illegible] the operation, unless performed [illegible] growing bone, or, in adults, where there is a sturdy involucrum around the sequestrum, must result in coalescence of the elbow- and shoulder-joints—that is, the radius and the ulna come to articulate with the glenoid fossa of the scapula. Such an operation has been performed, and with preservation of useful [illegible] But seldom, however, will the bone be so badly shattered by gunshot or by crushing injury, or so extensively involved in disease, osteomyelitic or neoplastic, as to require such heroic treatment.

The incision passes through the deltopectoral groove above, and the external bicipital groove below, so that it is bounded, from above downward, externally by the deltoid, the triceps, the brachioradialis, and the extensor carpi radialis muscles, and internally by the pectoralis major, the coracobrachialis, the biceps, and the brachialis anticus muscles. To be sought for and retracted from above downward are: In the deltopectoral groove, the humeral branch of the acromiothoracic axis artery and the cephalic vein; a hand's breadth below the acromion, and winding from without inward, the circumflex nerve accompanied by the posterior circumflex artery; in the musculospiral groove, which crosses the posterior surface of the shaft in its upper portion obliquely from above and within downward and outward between the external and the internal heads of the triceps muscle, the musculospiral nerve, which in the lower third of the shaft leaves the termination of the groove and passes forward and inward between the brachioradialis muscle externally, and the brachialis muscle internally; and finally, in the lower third, between the biceps brachii and the brachialis muscles and the musculocutaneous nerve. Having reached the bone, the periosteum is incised and then elevated with the sharp rugine, first at the center of the shaft for the entire circumference, where the bone is divided, and then along each half, carrying off the successive muscles encountered as each joint is approached, where the capsule is finally lifted off and the bone removed. The incisions through the skin, the superficial fascia, the deep fascia, the periosteum and the capsules are then closed in inverse order. Drainage may or may not be provided for, according to the judgment of the operator. Support by a gypsum splint that has been moulded to the upper extremity previous to operation, and that suspends it securely from the shoulder, is now obtained, provided the humerus is expected to reform. Otherwise the plaster-of-Paris must be moulded after the operation.

Resection (partial removal) of the humerus usually furnishes excellent results, because we are dealing with a bone that possesses a superior blood supply, and one that is not handicapped by the necessity of supporting weight. It takes an intramedullary graft as well as, or even better than, any other bone in the body. The incision is made as for excision, but spanning only as much length as is necessary. Resection of the head and of the lower extremity of the humerus are discussed, respectively, with excision of the shoulder-joint and of the elbow-joint.

Excision of the Shoulder-joint.—[illegible] Bent of England, 1774, probably did the first excision; the elder Moreau probably the first complete excision, 1786. In the Schleswig-Holstein campaign (1848), in the Crimean War 1855 [illegible] (1861–65) the operation gained greatly in prominence and has since then become fully established.

To obtain a nearthrosis or a good [illegible] the line of section in the humerus must be below the

tuberosities, to which are attached the rotators, and above the adductors. In all cases as little is sacrificed as is possible, in order that the functions of the forearm and hand may be preserved in their entirety. In children, in whom the growth is almost finished, operations with sacrifice of the muscular attachments and with little loss of the humerus give good functional results with either a nearthrosis or a pseudarthrosis. In adults, especially if the periosteum is not saved and the muscular attachments have been sacrificed, ankylosis or a flail joint will result, for the periosteal activity in adults is often wanting and no reproduction takes place.

In all cases the constant tendency to forward displacement of the humerus must be avoided. In all cases the humerus must be held in contact with the scapular border or the glenoid cavity in order to obtain a fixed but movable joint upon which the muscles may move the humerus. The mobility of the scapula compensates in great measure for immobility at the glenohumeral union.

Indications for Excision of the Shoulder-joint for Injury.—In slight injuries and in gunshot wounds, expectant treatment and, at the most, a partial excision are indicated. In severe injuries to the head of the humerus, and in comminuted fractures from gunshot wounds with the nerves and vessels intact, a primary excision is indicated. In severe injury to the head of the humerus and to the acromion process and the scapula, the operation is not necessarily contraindicated, provided the nerves and vessels are intact. In case the latter are involved, amputation is in all probability the only successful issue. In case the nerves are injured, the main vessels escaping, and provided the injured nerves can be sutured, amputation should give way to excision of the joint and suture of the nerves. In some cases of compound dislocation or of old unreduced dislocation, with or without fracture through the surgical neck of the humerus, excision has been made necessary; yet these cases are becoming more and more infrequent, owing to the aseptic treatment and to the earlier reductions by incisions (cf. Dollinger [11] and Thomas [12]).

1. No better authority on the unreduced dislocation of the shoulder-joint can be quoted than Souchon,[13] who maintains: I. That operation is justifiable only in recent cases in full-grown subjects of sufficient age to insure no great shortening from want of growth in the bone. II. That excision should be performed in all instances except when the head and glenoid cavity are in good condition; when reduction can be accomplished without great effort or extensive dissection; and when the head, once reduced, readily remains in place.

2. In fracture of the upper part of the surgical neck of the humerus and dislocation of the head, reduction of the dislocated head and plating of the fracture will be preferable to excision (McBurney); but when union fails and the joint becomes useless, or if the dislocated head cannot be reduced without too extensive interference with its nutrition, it must be removed (Cotton[14]).

3. In recurrent dislocations excision has been performed not infrequently, yet attempts at more conservative, *e.g.* reefing the capsule, methods are recommended by Burrell and Lovett.[15]

For Disease.—Here partial and complete excisions are indicated, although the functional results are not much better than in cases of ankylosis following expectant treatment. 1. In tuberculosis and in the destruction of a joint following epiphysitis and suppuration, gonorrheal infection, injury and infection, or from suppurative subdeltoid bursitis, partial or complete excision is indicated as soon as conservative surgical treatment fails to cure. 2. In ankylosis following acute rheumatic arthritis and acute traumatic arthritis with suppuration, excision is indicated in some instances.

For Tumors Involving the Bones of the Joint.—Instances exist in which a part of the humerus has been removed for sarcomatous growths involving the joint. J. C. Bloodgood has emphasized that thorough resection, rather than amputation, is the operation of choice in giant-cell bone sarcoma, and that recovery without recurrence should follow in the majority of instances. Recent investigations, however, show that not all giant-cell sarcomata are non-malignant.

Anatomy.—The anatomy of the shoulder-joint is very simple. All the bony prominences in its vicinity can be easily felt. The groove between the pectoralis major and the deltoid, in which lie the cephalic vein and the acromiothoracic artery, is easily made out. The circumflex nerve and the posterior circumflex artery cross the humerus in a horizontal line one finger's breadth below the center of a line drawn from the acromion to the deltoid insertion. These two structures usually pass just below the capsular attachment upon the internal surface of the anatomical

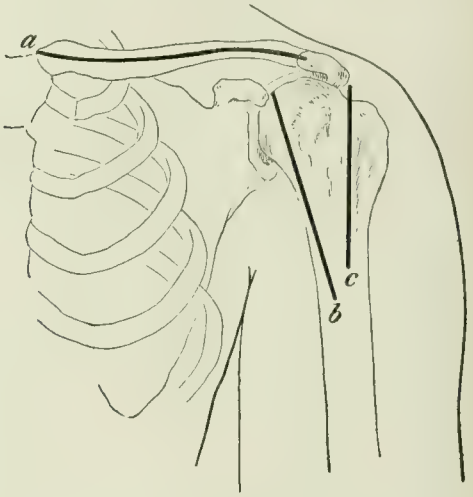

Fig. 2182.

neck, which point is opposite the so-called surgical neck of the humerus—the point above mentioned. The upper epiphysis becomes united to the shaft at twenty years. The deltoid muscle is so situated that the only place where it can be divided without injuring a portion of the nerve supply is close to the margin of the acromion process and of the spine of the scapula. This method of incision, recommended formerly by Nélaton, Neudörfer, Perrin, and Gurlt, avoids injury to the circumflex nerve and at the same time permits union of the muscle to the bones without atrophy of the muscular bundles. As a result, the humeral end is held in contact with the glenoid cavity or the border of the scapula in a firmer and stronger manner than can be obtained when atrophy of muscular fibers follows operation. This method of entering the joint is not convenient for observation of all parts of the articulation, especially of the anterior portion.

Another method of entering the joint is by means of incisions which traverse the deltoid muscle anteriorly. There are two of these incisions. One (Baudens, Malgaigne, and von Langenbeck) divides the anterior fibers of the deltoid muscle and necessarily paralyzes the anterior fibers of this muscle. (Fig. 2182, *c.*) Its field of observation and manipulation is a direct and extensive one. The other anterior incision (Ollier) passes nearer the interval between the pectoralis major and the deltoid muscles, paralyzes less of the deltoid muscle, and gives an operative field quite as good as that obtained by the Langenbeck incision. (Fig. 2182, *b.*) The posterior incision is anatomically

the better one, but incisions must be made to expose diseased areas and to render possible a full inspection of other portions of a joint than those thought to be alone involved. For this reason incisions which traverse the anterior portion of the deltoid muscle have been selected by most surgeons as the best.

Two methods of operation will be described, one by the anterior incision, the other by the posterior incision. Both methods should be performed subperiosteally if possible, since the partial reproduction of bone greatly aids the function of the joint by giving a more perfect fulcrum for the muscles of the shoulder (von Langenbeck and Ollier).

Operation by the Anterior Incision.—The patient is placed upon the back with the elbow slightly raised from the side and the hand resting upon the iliac spine of the same side. An incision is begun at the outer extremity of the coracoid process, and descends over the deltoid muscle parallel to its fibers (*i.e.* slightly outward) for a distance of from six to ten centimeters (Ollier, Hueter). The muscle is exposed in this incision. The muscle is incised parallel to its fibers, and the capsule, the humerus, and the coracoacromial ligament are exposed. The borders of the wound are now retracted and the bicipital groove in the humerus is noted. The capsule is divided longitudinally and externally to the sheath containing the biceps tendon. This division of the capsule extends above as far as the glenoid ligament. Below, the capsule and the periosteum are divided close to, but external to, the commencement of the bicipital groove in the humerus. With the rugine when one can, and with the knife when necessary, but always with an instrument with a keen edge, the periosteocapsular attachment of the internal flap is separated along the internal ridge of the bicipital groove, across the groove, and beyond the lesser tuberosity. To facilitate this work the arm is rotated outward, and as one approaches this tuberosity the head is made prominent in the wound by lowering the elbow during the act of rotation. In this manner, with good retraction, the capsule and the periosteum, or the capsule alone, may be separated beyond the insertion of the subscapularis musle. After this is accomplished the arm is returned to its original position and the separation of the periosteum and capsule of the external flap is commenced.

With a retractor beneath the capsule, the flap is raised and the separation of the capsule and the periosteum over the tuberosities and below upon the shaft is commenced. This is facilitated by rotating the arm inward while it is slightly adducted and the elbow is lowered. This maneuver is continued until the attachments of the supra- and infraspinatus and teres minor muscles are passed.

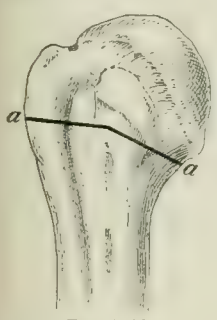

Fig. 2183.

The arm is now allowed to hang to the side of the table in a vertical position, and, when the retractors separate the flaps and the biceps tendon is drawn aside, the head is pushed upward through the wound and presents itself to view. The capsule and the periosteum are now cleared from the internal surface of the shaft, and when they are sufficiently so the saw is applied. During the section of the bone the head is held firmly with the long-toothed forceps while an assistant grasps the arm and steadies it.

Gigli's saw or a bow saw (Helferich's) is usually preferred in making the section. The line of section is from within outward and from below upward for one-half the diameter of the bone. For the rest the section is more horizontal (Fig. 2183, *aa*). As much of the shaft of the bone must be saved as is compatible with removal of the [illegible] should be made just to [illegible] possible. In such a [illegible] humerus will act as a fulcrum [illegible] in elevating the arm, and a [illegible] retained than when the section is nearer or through the surgical neck. The glenoid [illegible] and is curetted or cut away with [illegible] forceps. If this is necessary, the capsule and the insertions of the triceps and [illegible] be freed from the bone before its removal.

In cases of bony ankylosis, the [illegible] divided, and when the humerus is movable the excision may be completed as above described [illegible] saw through the humerus first and subsequently extirpate the head from its capsular and muscular attachments.

In tuberculous diseases, much time must be spent in removing the synovial membrane and clearing up the sinuses and the bursæ involved. When oozing is present, these cases are best partially sewed and tamponed for several days, but when hemorrhage is fully stopped they should be sewed up completely. The same holds true for other infections and for tumors. When the hemorrhage has been checked, the capsule and the periosteum are sutured with catgut. The deltoid is held together by catgut sutures involving a few of its fibers, but sufficient to close the opening. Drainage when required may be obtained by an opening through the capsule posteriorly. The skin is sutured with silk or silkworm gut.

If the fat-fascia flap is interposed to obtain a movable joint, it is taken from the surface of the deltoid, placed over the divided end of the humerus, and sutured to the capsule by chromic catgut. Where the anterior incision is employed a strip of the deltoid is taken from the front of the clavicle, but the posterior incision gives even more favorable results. Here the flap is taken from the fibers attached to the spine of the scapula and is stitched to the intact anterior wall of the capsule.

The position of the arm should be one of slight abduction, with the humerus pushed upward and backward and in contact with the glenoid cavity or the border of the scapula, where it is retained during the dressing by chromicized catgut sutures inserted before closing the capsule.

The Method of the Posterior Incision.—This method of incision is recommended by McCormac and Kocher. McCormac recommends it when the site of section in the humerus is to be above the tuberosities. Kocher believes that this method is advantageous in allowing perfect drainage and in preventing the forward dislocation so frequent after excision by leaving intact all that part of the joint and muscle attachment between the biceps tendon and the lower border of the subscapularis muscle. His method of incision, he believes, overcomes the interference with the exposure of the joint produced by the prominent acromion, and likewise avoids the danger of injury to the circumflex nerve, as it passes close to the humeral attachment of the capsule and the teres minor muscle. His method leaves the deltoid practically uninjured, so that its action in elevation of the arm suffers in no degree (Fig. 2184).

An incision is made, passing [illegible] clavicular articulation, over the prominence of the shoulder, along the spine of the scapula to its middle. From here the incision inclines in a curve downward toward the posterior axillary fold, ending about two fingers' breadth before reaching it. The upper limb of this incision divides the tissue over the acromioclavicular joint and the spine of the scapula, exposing each. The lower limb divides the tense fascia close to the posterior border of the deltoid muscle and exposes the muscle for a distance of [illegible] centimeters from the spine of the scapula. The [illegible]

cular fibers of the deltoid muscle which are inserted into the spine behind this incision must now be divided. This is the only portion of the muscle which is divided and is deprived of action. The trapezius muscle is next separated subperiosteally as far as the acromioclavicular articulation from the upper border of the spine of the scapula. Likewise, upon the lower border of the spine of the scapula, the deltoid origin is separated subperiosteally as far forward as the spot marked by the junction of the acromion process and the spine of the scapula. At this point the spine is separated from the acromion process either with the chisel or, better, with the Gigli saw. Care must be exercised not to injure the suprascapular nerve as it passes from the supra- to the infraspinous fossa. It is well also to make two drill holes before dividing the spine from the acromion process, so that they may be more easily sutured at a later period.

When this separation is completed, the acromion process with the attached deltoid muscle is luxated forward. The deltoid muscle is thus raised from the teres minor, the infraspinatus, and the supraspinatus

Fig. 2184.—(After Kocher.)

muscles, to which it is but loosely attached by connective tissue. After the dislocation of the acromiodeltoid flap, the insertion and the muscular bellies of these three muscles which cover the humeral head are exposed. The elbow is now brought forward and the arm is rotated outward. Along the upper border of the supraspinatus muscle an incision is made from the margin of the glenoid cavity to the greater tuberosity, exposing the tendon of the biceps muscle in its whole length within the joint. The outward rotators are next loosened subperiosteally from the greater tuberosity, and, while still attached to the periosteum of the shaft, are retracted posteriorly. If one wishes, a small part of the tuberosity may be cut away with the chisel, leaving thus a nucleus for the future development of a new tuberosity (Vogt's method). The biceps tendon is now loosened from the bicipital groove and is drawn forward. The insertion of the subscapular muscle is seen at its attachment to the lesser tuberosity. It should be separated subperiosteally and drawn forward and inward. The circumflex artery and nerve are to be avoided at the lower border of this muscle. As soon as the head is thus freed, it can be easily protruded through the wound. After it has been removed, the glenoid cavity should be freely exposed and to an extent which is unattainable by any anterior incision. This exposure is best accomplished, after the head has

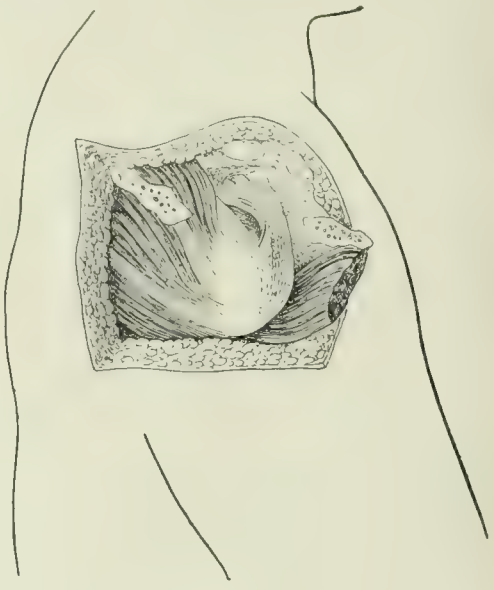

Fig. 2185.—(After Kocher.)

been removed, by exerting traction upon the elbow while it is held in the position of adduction. The importance of the exposure of the glenoid cavity in tuberculosis of this joint cannot be questioned, and therefore this method has its specific application.

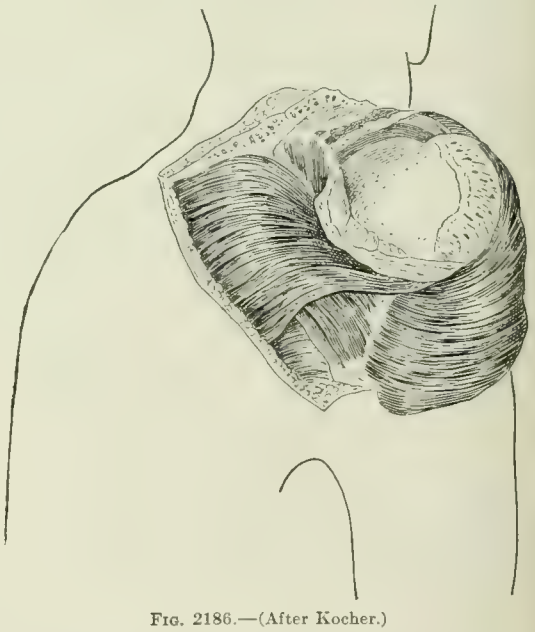

Fig. 2186.—(After Kocher.)

After the synovial membrane, the bursæ, and the bones are removed, the capsule and the periosteum are sutured, and the wound is closed. If drainage is necessary, the capsule should be incised below the border of the teres minor, and care taken to avoid

the circumflex nerve and artery as it emerges beneath the muscle. These are easily recognized, however, since the field is so well exposed. After this is accomplished, the spine of the scapula and the acromion should be sutured. The trapezius and the deltoid are sutured over the acromion or spine of the scapula, if necessary; if it is not thought necessary, they are left unsutured. The skin should be sutured separately.

Sir William MacCormac advised entering the joint between the teres minor and the infraspinatus muscles, clearing the infraspinatus, supraspinatus, and the subscapularis muscles and the biceps tendon forward, until the bone is free, and subsequently clearing the teres minor muscle with the capsule posteriorly. In some instances this is undoubtedly a good method of approach after the deltoid has been retracted forward.

After-treatment.—The main point in the after-treatment seems to be the retention of the head in contact with the glenoid cavity or with the border of the scapula. This contact may be secured by the use of chromicized catgut, which lasts long enough to insure no slipping during the primary dressing. A large pad made like the Stromeyer's cushion is now placed in the axilla, and the arm resting upon this pad is secured to the side, while the forearm is supported by a sling. This pad supports the humerus, fixes it, and prevents the tendency which the pectoralis major and the latissimus dorsi have, to displace the upper end of the humerus in an inward direction, beneath the coracoid process. This tendency will be more difficult to counteract if the external rotators have been divided.

The first dressing is not changed for from six to ten days if possible. The movements of the fingers, wrist, and elbow are gently exercised daily from the very first. It is useless to begin moving the shoulder until the deep parts of the wound are sufficiently healed, *i.e.* usually in the second or third week. In this manipulation abduction must be made with care, for fear of dislodging the head and forcing it beneath the coracoid process. Daily application of massage, electricity, and heat to the muscles of the shoulder are very useful in preventing too extensive ankylosis. The deltoid and the rotator muscles should be daily exercised by appropriate manipulations. This should be continued for from four to six weeks, after which the patient must carry out his exercises, such as bringing a gun to the shoulder, lifting weights with the arm abducted, and appropriate exercises with the various kinds of gymnastic weights and pulleys. The after-treatment must be maintained for a long time in order to obtain the best results. Langenbeck refers to a case in which the arm increased in strength for two years following the operation.

Results.—According to Culbertson, the mortality was as follows: For gunshot wounds (855 cases,) 31.44 per cent.; for disease (116 cases), 15.84 per cent. According to Otis, the results were as follows: Out of 2,369 cases of gunshot wounds, 577 of which were treated by the expectant method, there were 951 cases which were treated by excision, with a mortality of 36.6 per cent., and 841 cases which were treated by amputation, with a mortality of 29.1 per cent. The mortality for the 2,369 cases was 25.1 per cent. According to Souchon, the results, in cases of old irreducible dislocations, with or without fracture of the humerus, were as follows: In those treated by reduction, the mortality was 10 per cent., and in those treated by excision it was 12 per cent.

The Functional Result.—Usually flexion and extension are good; adduction is also usually good. Rotation and abduction are usually feeble. The tendency in this joint is toward ankylosis rather than toward a flail joint. The subperiosteal method (Ollier) gives the most perfect functional result, and should be practised whenever feasible. According to Gurlt, the results in 213 cases were as follows: Very good, almost perfect, in 1.87 per cent.; good, but useful, in 42.25 per cent.; moderate, of limited use, in 47.88 per cent.; bad, useless, in 8.0 per cent. In the German wars Langenbeck [illegible] ment gave at least as good results as the [illegible] which were then performed. [illegible] excision of the head of the humerus [illegible] good in 2 instances, while in 31 cases the shoulder hung like a flail, and the elbow, hand, and fingers were more or less useless. On the other hand, in 54 cases treated conservatively, [illegible] in 43 instances, but the elbow, hand, and fingers continued to be useful. "When the subperiosteal method is employed and the supraspinatus, the infraspinatus, the teres minor, and the subscapularis muscles remain in connection with the periosteum of the shaft of the humerus, a flail joint will not result." "The good results are obtained when the subperiosteal method is carried out." He reports 8 cases with excellent results. Wegner also reports an excellent result following excision of this joint for caries sicca (tuberculosis).

Scudder and Barney,[16] in reporting the late results in nineteen cases of excision of the shoulder-joint, found that there will be limited power of the shoulder; a diminution in strength; limited active motion in abduction and adduction, and in backward and forward swing; atrophy, and possible formation of new osseous areas about the old joint from detached periosteum; and that deformity and pain may persist.

Excision of the Scapula.—Excision (total removal) of the scapula—the alternative of interscapulothoracic amputation—is more frequently indicated than excision of the bones that have been considered above, owing to the relative frequency with which the bone is the seat of osteochondroma and of sarcoma, central or subperiosteal. Extensive shattering from a bullet or severe crushing injury, and widespread osteomyelitis that has resulted in necrosis, are additional indications. Since the bone is for the most part thin and flat, it is more liable to succumb to infection and less likely to react with a good involucrum than a cylindrical bone. The operation was first carried out by Langenbeck, who, in 1855, excised the scapula with three inches of the clavicle, while preserving the arm (Ashhurst[6]), and it has since been performed by Agnew, Billroth, Esmarch, Kocher, Spence, Syme, and many others. The two features of removal of the scapula are first the control of hemorrhage by putting a clip temporarily upon the third portion of the subclavian artery, thus providing for a point of retreat, and second, retention of the parts that enter into the shoulder-joint—the neck with the glenoid cavity, and the acromion and the coracoid process, if possible, thus substituting resection for excision. After excision, the clavicle is left projecting, and the upper portion of the humerus is drawn inward by the pectoralis major and the latissimus dorsi muscles until it lies over against the ribs, as in subcoracoid and subclavicular luxations. Here the head of the humerus forms a bed for itself, about which all movements center. Although the chief function of the scapula—that of elevating the arm above the horizontal—is lost, yet a fairly useful limb may result, one that can perform work within a radius of ninety degrees from the side of the body, and that can even lift weights.

Preliminary to the incision, the third portion of the subclavian artery should be exposed in the classical manner, and a Matas metal clip applied, so as temporarily to occlude the vessel. This is particularly indicated where the extensive exudations of trauma or the widespread infiltrations of malignant neoplasms obscure, displace, or directly involve the periscapular vessels. The tumor itself may be dangerously vascular, as in aneurysmal sarcoma. If preferred, a stout ligature may be passed around the artery with the aneurysm needle and left untied, and a place

of safety will be provided, to which to retreat in case of unexpected, sudden, copious and alarming hemorrhage which, if an aneurysmal sarcoma be present, may directly terminate in lethal exitus.

The incision is composite, consisting of a horizontal (spinous) limb, and a vertical (vertebral) limb, which meet almost at a right angle—that is, at the angle the degree of which corresponds to that between the spinous process and the vertebral border of the scapula. The spinous limb begins over the acromioclavicular joint and passes along the spinous process to the vertebral border. The vertebral limb begins at the superior angle and passes parallel with and slightly to the outer side of the vertebral border to the inferior angle. The two triangular flaps of skin thus marked out are turned back. The deep fascia covering the muscles is now exposed, and the latter are dealt with according to the disease for which the operation is performed. In the presence of malignancy, the muscles may be so infiltrated, and the tumor so vascular that it may be advisable not to detach them from the bone. In traumatic cases and in those resulting from infection, the muscles are freed from the scapula by successive steps as follows: Along the upper border of the spine the origin of the trapezius, and along the lower that of the deltoid, are separated. Along the vertebral border, from above downward, the levator scapulæ, the rhomboideus minor, and the rhomboideus major are similarly dealt with. Near the superior angle the posterior scapular artery is ligated. By retracting the vertebral border outward the serratus magnus is cut through. Along the superior border the origin of the posterior belly of the omohyoid muscle is severed, the suprascapular artery ligated near its notch, and the suprascapular nerve cut. The acromioclavicular joint is entered, freed, and the conoid and trapezoid ligaments separated as encountered. The coracoid process is freed of its muscles—the pectoralis minor, the short head of the biceps, and the coracobrachialis. The capsule of the shoulder-joint, together with the supraspinatus, the infraspinatus, and the subscapularis muscles, is separated. Along the axillary border the teres major and the teres minor muscles are freed, and the subscapular artery and vein ligated. The bellies of the supraspinatus, the infraspinatus, and the subscapularis muscles are removed with the bone. The flaps are replaced, sutured together, and twenty-four-hour drainage instituted. The upper extremity is immobilized by a fixation dressing. In certain cases it may be wise to leave the temporary ligature on the subclavian artery *in situ* for twenty-four hours.

Quénu and Renon have shown that the preservation of the acromion, if possible, is worth while since the subsequent function is greater if it is saved, and this is especially true if the remains of the capsule and the muscle stumps are sutured to it.

According to Buchanan (1900) the mortality with total excision is 15.3 per cent. (72 cases); with partial excision it is 18 per cent. (92 cases).

Resection (partial removal) suffices in many cases of trauma or disease of the scapula. The acromion or the spinous process may be removed through a single transverse incision. The superior or the inferior angle may be resected through a V-shaped incision that outlines its borders. The body of the scapula is removed through the same incision as for excision. Resection of the glenoid cavity is considered under excision of the shoulder-joint.

Excision of the Clavicle.—Excision (total removal) of the clavicle (Fig. 2182, *a*) was first performed in 1811 by Dr. McCrearry of Kentucky and next, in 1823, by a German surgeon, Dr. Meyer (Ashhurst). The indications are the same as for other bones. While in traumatic and in osteomyelitic cases the operation may be performed with safety and facility because subperiosteally, in malignant cases great caution must be exercised, lest the large vessels and nerves in intimate relation with the bone be injured. In these cases it is usually out of the question to work subperiosteally. The veins that lie so close to the bone, and which may be much enlarged and even involved in the neoplasm, are particularly liable to give trouble. In the case of the great neurovascular bundle—which approximately corresponds to the middle third of the bone—a margin of safety is afforded by the interposition between it and the clavicle of the subclavius muscle, invested by the well-developed clavipectoral fascia. So, too, the bundle itself is enveloped by the dense prevertebral layer of the deep cervical fascia, which it carries down into the axilla. In the hands of the careful operator, then, the chief concern will be the avoidance of venous bleeding, since for him the neurovascular bundle protects itself, unless extensively infiltrated in a malignant neoplasm, in which instance the tumor is probably inoperable.

The incision begins just to the outer side of the acromioclavicular joint and passes along the anterior border of the clavicle, the curves of which it follows to the sternoclavicular articulation of the *opposite* side, there being severed the skin, the superficial fascia with the platysma myoides muscle, beneath which are the supraacromial, the supraclavicular, and the suprasternal branches of the superficial cervical plexus, the deep fascia, and the periosteum. Working beneath the last with the sharp rugine, it is elevated first circumferentially from the center of the bone if the bone be free, but if involved in a neoplasm a healthy portion should be chosen, if available. Where thus exposed the bone is divided and each half lifted from its bed and cleared subperiosteally if possible out to its articular extremity, where the capsule is pushed off. At the sternal end of the inner portion great care must be exercised, lest by a slip of the rugine the large innominate vein be penetrated. Such a calamity is avoidable by always keeping the rugine in *absolute apposition* with the bone, and by not dragging on the soft parts. *Upon these observances more than upon anything else depend the safety of the operation and the freedom from hemorrhage.* The rent in the capsule and the incision in the periosteum are closed, drainage is instituted if necessary, and the arm is immobilized as in fracture of the clavicle—preferably by the method recommended by G. G. Davis, in which a gypsum case is so fashioned as to include the trunk and the upper extremity.

Although the chief functions of the clavicle are to steady the shoulder and to afford leverage for the muscles, yet the rearrangement of parts after its sacrifice is such that a considerable degree of function may be expected. Particularly true is this in young, growing bones, in which the actively productive periosteum may faithfully reproduce the bone in its original dimensions.

Resection (partial removal) of the clavicle is not only the method of choice, but also the one that will be required in the large majority of cases.

The middle third of the clavicle may be resected to gain access to the lowest portion of the subclavian triangle, either as a preliminary step to other operations, as when ligating the subclavian artery previous to operations upon the axilla and to interscapulothoracic amputation, or for manipulations confined to the underlying region, as upon the brachial plexus. It may also be resected to fulfil the indications for excision when the injury or disease is limited in extent. Either end may be removed, as in excision of the sterno- or the acromioclavicular joint. There is the celebrated case of Dr. Mott, related by Ashhurst, in which excision occupied nearly four hours, and the bleeding was so profuse that about forty ligatures were required: fifty-four years later the patient came to the autopsy table, where it was found that one and three-quarter inches of the acromial end had not been removed at the operation,

making it, therefore, one of the early cases of true resection. The incision, of course, is made in the same line as for excision, but limited in extent.

Excision of the Sternum.—Excision (total removal) of the sternum has been performed by Koenig, for the following account of which we are indebted to Ashhurst. "In this remarkable case, the whole sternum is said to have been removed on account of a sarcomatous tumor by which it was occupied; the pericardium and both pleural cavities were opened in the operation, the wound became gangrenous, and the heart was afterward surrounded with pus; notwithstanding this, the wound slowly healed, and the patient ultimately recovered." The nearest approach to this operation nowadays is seen in Brauer's cardiolysis, which involves chiefly the gladiolus, and which therefore is but a resection.

The incision may be vertical, T-shaped, or crucial. The costal cartilages are cleared and divided with care close to the sternum. The latter is then drawn forward and disarticulated from the clavicles. Extreme caution must be conscientiously exercised in clearing the posterior surface of the sternum from below upward. In the upper portion, by hugging the bone very closely, injury to the innominate veins may be avoided. The internal mammary arteries lie a half-inch wide of the margins of the sternum, and should not come into question. The soft parts are approximated by sutures, and drainage provided if necessary. The operation is completed by applying a dressing and supporting the thorax with wide strips of adhesive plaster or with a jacket. If in the course of the operation the pericardial, the pleural, or the peritoneal cavity is opened, it should be immediately closed by suturing, to prevent infection with its attendant dangers.

Resection (partial removal) of the sternum dates from the trephining of Galen for osteomyelitis and its sequelæ. It may be performed for evacuation of a mediastinal abscess, but this is more safely done by an incision alongside of the bone (Ashhurst). According to the same authority, Larrey removed about half of the sternum in a case of compound fracture, and Linoli, an Italian surgeon, excised the ensiform cartilage, which was bent backward, to relieve uncontrollable vomiting. In certain methods of approach to the contents of the mediastinal spaces (thymus, etc.), as well as in Hirschberg's operation for creation of a midsternal joint for mobilization of the thorax, and for other conditions that may suggest themselves, resection may be performed.

The incision is made as long as is necessary in the course of any of the three described as being suitable for excision. Because of its flatness, the sternum lends itself to the methods employed upon the skull, as, for example, trephining and removal of bone by the gouge. The edges of the incision are sutured and drainage provided if necessary.

Excision of the Ribs.—Excision (total removal) of a rib, except in the case of the vertebral (floating) members, is, in a literal sense, extremely rarely indicated, the nearest approach being in Schede's operation of thoracoplasty, in which the entire rib is removed with the exception of the head and the neck, thus being in effect a resection.

The incision for excision begins anteriorly over the chondrosternal joint and traces the rib—midway between the upper and the lower border—back to the costovertebral joint. For the upper ribs, this posterior part of the incision runs along the upper border, just above the transverse process. The knife passes directly through the skin, the superficial and the deep fascia, the muscles and the periosteum to the bone. Working subperiosteally, the rib is cleared first at its center, observing the usual precautions for the contents of the subcostal groove. It takes the utmost skill to avoid penetration of the endothoracic fascia and the pleura. The bone is now divided in its center, and each [illegible] joint and removed. The edges of the [illegible] that were cut through are [illegible] completing the operation. For the removal of [illegible] adjacent ribs the incision may [illegible] an intercostal space. When dealing with the intercostal vessels, if exposed in the field of operation, it is always best to secure them by ligation, whether injured or not, for after operations they may give rise from trauma or ulceration in the presence of disease, and serious if not fatal hemorrhage ensue. The collateral anastomosis is so free that the loss of one or more intercostal arteries pales into insignificance, when compared with the safety of the patient.

Resection (partial removal of a rib) is an [illegible] operation that was known to Celsus. It varies in extent from the mere trephining of a rib to the extensive thoracoplasty of Schede. While most frequently indicated to drain an empyema, yet the rapid advances in the surgery of the chest increase the indications by constantly creating new methods of approach to thoracic viscera that hitherto were not subjected to operative attack. Aside from infection and its sequelæ, hemorrhage from an intercostal artery, and tumors, the indications for rib resection, then, are those of thoracotomy and thoracoplasty, as well as of transphrenic laparotomy; it is also performed to gain more room when dealing with the kidney. What portion of a rib and how many ribs to resect are questions that are answered by the condition for which the operation is performed.

The incision for resection is made along the line of the rib, as in excision, but is necessarily shorter.

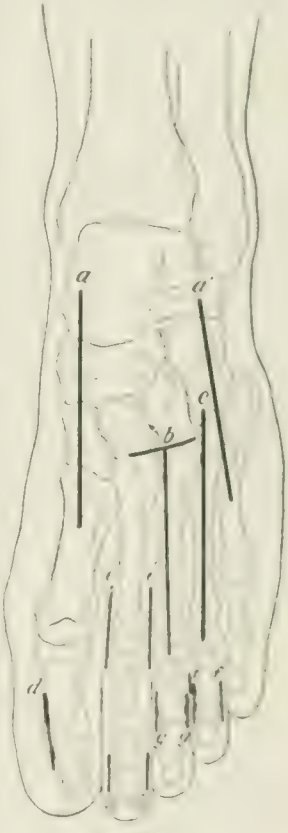

Fig. 2187

Excision of the Lower Extremity.—The small joints of the foot occasionally require excision. Corresponding joints in the toes are removed in the same manner as those in the fingers. As a matter of fact, excision of the toes is seldom done, since their deformations do not demand it.

Excisions of the metatarsophalangeal joints are performed in the same manner as in the hand. The incisions are placed to either side of the extensor tendon in the second, third, and fourth metatarsophalangeal joints, to the inner side of the tendon in the first metatarsophalangeal articulation, and to the outer side of the tendon in the fifth metatarsophalangeal joint.

Of these joints, the metatarsophalangeal articulation of the great toe is not infrequently excised for hallux valgus. As these cases are quite often complicated with a bunion which requires removal at the same time, this incision is a semilunar one. It extends from a point on the metatarsal bone, two and one-half to three and one-half centimeters above the

joint. It descends in a curve over the lower quadrant of the bunion until it reaches its mid-point, whence it ascends in a curve to the center of the outer border of the first phalanx. This flap with the deep connective tissue is dissected from the bunion until its base is reached. The adventitious tissue and the bunion are now removed, after which the subperiosteocapsular method is pursued in freeing the ends of the bones. When the periosteum and the capsule are

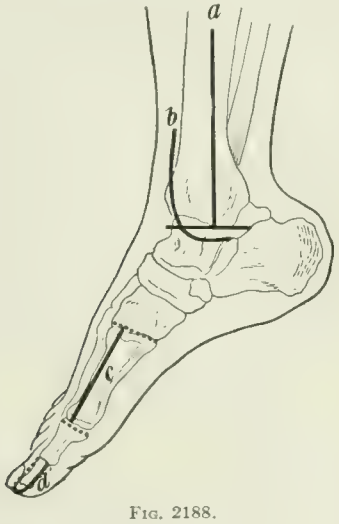

Fig. 2188.

loosened to beyond the center of the articular surfaces, the ends of the bones may be made to protrude through the wound. (Fig. 2189.)

They may now be removed completely or partially as desired. Since it is very necessary to retain the sesamoid bones, the separation of the periosteum and of the capsule upon the inferior surface of the joint must be done with care. After removal of the articular ends of the bones they are placed in apposition and sutured with catgut if one desires an ankylosis. If a pseudarthrosis or nearthrosis is desired, no suture of the bones is made, but the capsule is closed over their ends.

Many deformities in hallux valgus, where the bunion and the deformity are not great, may be corrected by a cuneiform osteotomy of the lower third of the metatarsal bone, and such an operation is to be advised in the minor cases of this condition.

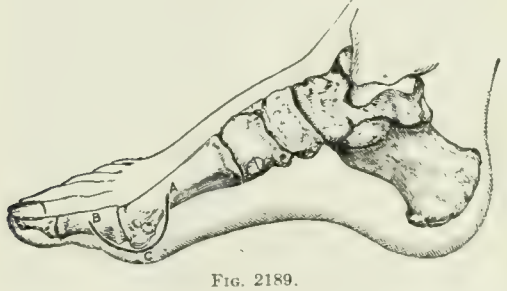

Fig. 2189.

A recent article by Singly[17] describes a modification of Fowler's operation, in which the incision is placed on the *outer* side of the joint. The advantages are summarized as follows: (1) The incision is in a location where, even on theoretical grounds, it cannot be objectionable. (2) It affords a much better exposure of the diseased ends of the bones than any other method and permits accurate shaping of the new articular surfaces. (3) The joint is opened on the outer side, dividing the shortened external lateral ligament, an important step in avoiding recurrence. (4) Ankylosis is prevented and a new joint formed by the interposition of a fatty fibrous flap.

Excision of the fourth metatarsophalangeal articulation is the recognized method of relieving that painful condition of the foot known as metatarsalgia, first described by T. G. Morton. This operation needs no special description farther than to state that it is better to remove the fourth toe with the head of the metatarsal, as its retention is apt to leave a hammer toe. (Fig. 2187, *ee*.)

Excision of the Phalanges of the Foot.—The proximal, middle and distal bones of the toes may be removed by exactly the same methods which are applicable to the corresponding bones of the hand, *i.e.* a U-shaped plantar incision for the terminal, a dorsolateral incision for the middle, and a dorsolateral or two dorsolaterals for the proximal, if done at all. With the great toe and the little toe the incisions should be planned to avoid pressure on the scar. (Fig. 2188, *d*.)

Excision of the Metatarsals.—Again the rules applicable to the excision of the metacarpals will serve without modification. (Fig. 2187, *b, c;* Fig. 2288, *c*.)

Excision of the Astragalus.—This operation is said to have been done as early as 1582 by a surgeon of Duisburg (Ashhurst). The necessity for the complete or partial removal of this bone seldom arises, but compound fracture or dislocation, if irreducible, or necrosis may demand its excision. There are two good methods which may be employed: (1) by the external curved incision, or (2) by the external angular and curved internal incision.

In the first method the incision commences about eight centimeters above the ankle at the anterior border of the fibula and passes downward external to the tendon of the peroneus tertius and the musculocutaneous nerve and then curves forward to the base of the fifth metatarsal. (Fig. 2190, *b*.) In deepening the wound the peroneus tertius is drawn inward and the extensor brevis digitorum outward, and in the intervening space the capsule of the ankle-joint is opened as well as the mediotarsal joint. The neck of the astragalus and the lower ends of the tibia and fibula are freed, the calcaneoastragaloid ligament is severed, and as much of the external lateral ligament as is necessary is divided. After separating the bone from the scaphoid and calcaneum by a strong knife, the foot is inverted forcibly and while in this position the astragalus is drawn out and the inner attachments divided. Care must be exercised at this point to avoid injuring the posterior tibial artery and nerve. The few remaining ligaments are now cut and the bone removed. The excision may be facilitated sometimes by early cutting across the neck of the bone, and, indeed, in cases of necrosis it is well to remove the astragalus piecemeal.

Hemostasis is not difficult but a temporary drain should be used. The tibial and fibular ends drop down upon the upper surface of the os calcis. Chromic catgut is used to close the deep wound and silkworm gut for the skin. The limb should be splinted in a removable plaster-of-Paris case with the foot at a right angle. Passive exercise with massage should be commenced within ten days, but a supporting dressing should be used for as many weeks.

The excision of the astragalus by the double-incision method is to be preferred where the tissues are firm and unyielding. As no attempt is made to preserve the periosteum or capsule the ankle is usually ankylosed. The vertical portion of the external angular incision commences on the anteroexternal surface of tibia, well in front of the external malleolus, and extends downward a distance of about six centimeters, and ends over the cuboid. (Fig. 2190, *c*.) From the center of this incision a short incision runs backward to the external malleolus. The vertical incision passes between the tendons of the peroneus

tertius and brevis, and when deepened it is possible, by extending and inverting the foot and retracting the tendons, to expose and divide many of the ligaments holding the astragalus to the scaphoid, os calcis, fibula and tibia. The internal curved incision commences on the antero-internal aspect of the tibia, passes in front of the internal malleolus and curves backward to end just below its tip. Through this incision the antero-internal surface of the astragalus is exposed between the tendons of the tibialis anticus and posticus. By everting the foot practically all of the remaining ligaments may be divided, and when the foot is again inverted the astragalus can be seized by lion-jaw forceps and removed through the external wound. The closure is similar to that employed in the single-incision method, but additional care must be taken to strengthen the parts by carefully suturing with chromic gut all portions of fibrous tissue that are loose.

According to the statistics of Hancock and Poinsot (cited by Ashhurst) about eighty per cent. of the patients upon whom total excision was done recovered with useful limbs, and nineteen per cent. died. These are preantiseptic statistics and doubtless to-day the mortality should be nearly nil.

Excision of the Os Calcis.—The total removal of this bone is rarely required, though partial excisions, or rather sequestrotomies for necrosis, are not uncommon. It apears to have been formally removed for the first time in 1814 by Monteggia.

Complete loss of the os calcis results in considerable disability; the plantar arch is destroyed and with it goes the natural elasticity of the foot; and furthermore there is always impaired inversion, eversion, and plantar flexion. If, however, the periosteum can be preserved, particularly that portion to which is attached the Achilles tendon, and if the patient is young enough to develop some regeneration of bone, the resulting condition may show very minor disturbance of function.

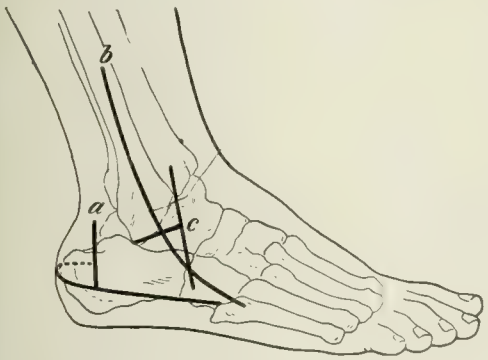

Fig. 2190.

The calcaneum may be satisfactorily excised through a horizontal curved incision supplemented by a short vertical incision. The first incision commences at the base of the fifth metatarsal, and passes backward and around the heel to the inner side where it stops far enough behind the posterior tibial artery and nerve to avoid their injury. (Fig. 2190, *a*.) This incision should be well above the margin of the sole, and is directly deepened to and through the periosteum. The vertical incision is about five centimeters long and is placed on the outer side of the foot in front of the tendo Achillis. Flaps are raised and the periosteum is elevated with a sharp rugine. This is not easy as the periosteum here is closely adherent but with care and patience much of it can be saved as well as the capsuloperiosteal structures of the calcaneocuboid and calcaneoastragaloid joints. It is a sound procedure in detaching the tendo Achillis to preserve a shell of bone after the method of Vogt [illegible] young every attempt should be made to [illegible] posterior epiphysis. (Fig. 2190, *a*.)

After the bone has been removed the [illegible] sutured in tiers, the wound drained, and the foot dressed at a right angle upon an anterior [illegible] as to avoid direct heel pressure.

Excisions involving either the tarsometatarsal, the tarsal, or the talotarsal joint, are rarely performed, because disease is scarcely ever confined to [illegible] of these several joints. It is rare to have only one of the seven* articular synovial cavities of the foot involved. Disease or infection from injury commencing in any one of these seven cavities soon spreads through the cancellous tissue of the bone to the neighboring synovial cavities, so that the process rapidly becomes a diffuse synovial, parasynovial, and periosteal one (Fig. 2191). For this reason excisions of single joints are rarely made on account of disease. In injuries to these joints and in deformities, congenital or acquired, excisions of single joints can rarely be performed in even minor grades of the injury or deformity. We must look upon the foot as a whole and operate without regard to the joints, with the sole idea of removing the condition for which we operate.

Fig. 2191.

There are several procedures which are applicable to injury or disease of this region: (1) Those of Bardenheuer and P. Bruns: (2) those of Wladimiroff-Milkulicz and Kümmell. For disease or injury situated between the bases of the metatarsal bones and the calcaneus and talus, Bardenheuer's method is especially applicable. In the majority of cases the involvement of the tarsal bones and the periosteal tissues is so great that an extensive exposure must be made in order to remove the diseased tissues completely. Where the disease involves the tarsometatarsal, the talocalcaneonavicular, and the calcaneocuboid articulations, the method of H. P. Watson (Jacobson's "Surgery," vol. ii., p. 707) is not satisfactory and a more extensive exposure is required. It is here that Bardenheuer's method is most applicable.

Anterior Tarsectomy.—An Esmarch bandage [illegible] applied. An incision is made through the skin, subcutaneous tissue, tendons of the extensores digitorum longus et brevis et proprius pollicis, and the cutaneous nerves, down to the bones from the first to the fifth metatarsal bones at their bases. From the extremities of this incision, two incisions are curved upward along the internal and external borders of the foot to beyond the [illegible] joint. These incisions also extend through to the bone, dividing the tendons of the peroneus tertius and of the tibialis anticus. If necessary, these lateral

* I. Between the first metatarsal and [illegible] bones. II. Between the second and [illegible] middle and external cuneiform bones [illegible] IV. III. Between the fourth and fifth metatarsal and the cuboid IV. Between the three cuneiform and [illegible] communicate with II. V. Between [illegible] VI. Between the scaphoid and the cuneiforms and the [illegible] VII. Between the talus and calcaneus.

incisions may be prolonged upon the metatarsal bones, the U-shaped incision being converted into an H-shaped one. This flap as marked out is dissected from the periosteum and the ligaments of the bones until it can be reflected above the level of the mediotarsal joints. Here it is best to enter the joint, dividing the ligaments upon the anterior and lateral surfaces, when, if the forefoot is firmly held and depressed, the plantar ligaments holding the calcaneus and scaphoid and the calcaneus and cuboid can be divided. This division frees the tarsus, and allows, as in Lisfranc's amputation, an easy separation of the tendons of the tibialis posticus, the peroneus longus, and the less important muscles from the tarsus as far as the bases of the metatarsal bones. At this point a blunt retractor is passed between the bones and subjacent tissues, and the bases of the metatarsal bones are sawn at the distal side of their articular surfaces. The articular surfaces of the calcaneus and of the talus are now sawn off (Fig. 2192). The disease involving the muscles and the sheaths of the tendons is next removed. The vessels are ligated, the Esmarch bandage is removed, and the sawn extremities of the bones are apposed and sutured with chromicized catgut. If the disease is not thoroughly removed, or if one so desires for any other reason, the wound may be packed until granulations appear, when a secondary suturing is done.

In this operation the tendons are rarely sutured. It has been found that in healing by granulation the fibrous cicatrix unites the tendons so that motion in the toes is often good. It is, however, advisable that the tendons be sutured whenever the wound treatment allows it. If possible, the tendons to the first toe should be sutured in all cases. In some cases sensation has returned though no suture of the nerves was attempted.

O. Wolff has presented 53 cases operated on by this method, in which the anterior tibial artery was

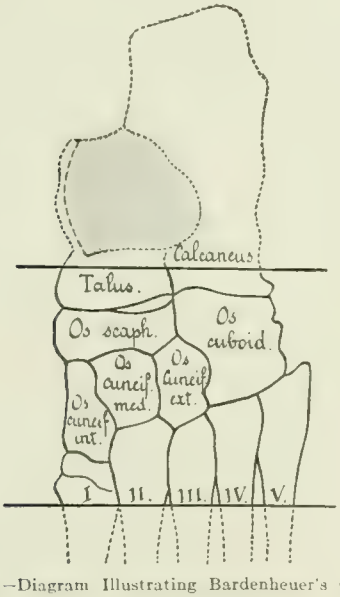

Fig. 2192.—Diagram Illustrating Bardenheuer's Operation.

cut. In 5 cases the posterior tibial artery was also cut. In 3 of these cases gangrene followed and required amputation. Of these cases, 42 were tuberculous in character, for which 9 complete tarsectomies, 7 partial with subsequent complete tarsectomies, and 13 partial tarsectomies were performed, with 29 complete cures. Two cases escaped subsequent observation. Three cases were amputated for gangrene and 8 cases remained under treatment at the time. In all the cured cases the foot remained a "flat" one, but the functional results were good.

Bardenheuer reported 17 cases of tuberculosis, in which none died as the result of operation. Twelve cases were cured with one operation, and of these 3 died subsequently of tuberculous meningitis; 3 required subsequent revisions before a cure was effected; 1 required amputation. One case of excision was due to loss of substance from injury; a cure resulted.

Fig. 2193.—Lateral View of the Bones after Bardenheuer's Excision of the Tarsus.

Tibioastragaloid Excision.—The statistics of Audry show that tuberculous disease involves the ankle, the talocalcanean, and the talocalcaneoscaphoid joints in fourteen per cent. of the tuberculoses in the foot, and that unless amputation be performed at the ankle (Syme's or Pirogoff's) some method must be found by which all of these joints can be opened and resected. Such a method was elaborated by P. Bruns in 1890. This operation, made a typical one by Bruns, was previously done in an atypical fashion by Textor, 1852, and Mulvaney, 1866, and has subsequently been elaborated by Heidenhain, Helferich, Cramer, Küttner, and Kummer.

The indications for this operation are the same as those for Pirogoff's amputation, namely, disease involving the talocalcanean, talonavicular, and talocrural joints, with foci within the bones. Its advantage rests in the fact that it preserves the forefoot and gives a more useful member than is obtained by an amputation.

The method is as follows: An Esmarch bandage is applied. In order to obtain sufficient exposure, an incision is made from one malleolus to the other in a broad curve over the dorsum of the foot in the neighborhood of the tarsometatarsal joints. This curved dorsal incision, first made by Houssey (Heyfelder)[18], and subsequently used by Bardenheuer in his excision of the tarsus, is at no disadvantage because of the division of the tendons and nerves. The flap thus marked out is deepened, passing above the peroneal tendons on the outer side and dividing upon the dorsal and internal surfaces the peroneus tertius, extensor longus digitorum, proprius hallucis, and tibialis anticus tendons, together with the branches of the anterior tibial and musculocutaneus nerves and the dorsalis pedis artery. This flap is dissected from the bones until the anterior tibial margin is reached. The talocrural joint is opened by a transverse incision which divides the anterior fasciculi of the lateral ligaments. The foot is pulled forward and depressed, when the middle and posterior fasciculi of the lateral ligament are divided as close to the astragalus and os calcis as possible. With further depression, the posterior ligament of the ankle-joint is divided transversely, exposing the flexor longus hallucis tendon. The astragaloscaphoid and the calcaneocuboid articulations are next entered and

the superior and lateral capsular bands divided. If the astragalus is now cleared upon its lateral surfaces and the knife is passed into the sinus tarsi and carried from before backward, toward the sustentaculum tali, the interosseous ligament will be divided. The astragalus is now held only by a few undivided capsular fibers of the posterior talocalcanean articulation and can be easily removed. The scaphoid, calcanean, and cuboid bones, the tibia and the fibula, are now inspected for disease, and if they are involved they should be treated as follows: The tibia and fibula are sawn so as to preserve their mortise shape. This is usually accomplished by cutting away the articular end of the tibia with the chisel or gouge, preserving its hollow shape, and by sawing the malleoli obliquely, leaving a small projecting edge beyond the surface of the tibia (Fig. 2194). The superior surface of the calcaneus is made to fit accurately the space between the malleoli. This will not infrequently require a removal of the sustentaculum tali. The calcaneoscaphoid and the inferior calcaneocuboid ligaments are now divided or separated from the inferior surfaces of the cuboid and scaphoid bones, so as to allow a vertical section with the saw. After this section, the anterior surface of the calcaneus is sawn in the same plane. The tendons, their sheaths, the ligaments and the muscles are next inspected, and if involved by disease they should be removed, after which the calcaneus is apposed to the tibia and fibula and to the cuboid bone. These bones are held in apposition by catgut sutures. The scaphoid bone will be seen to rest against the anterior margin of the tibia. The Esmarch bandage is now removed. The hemorrhage is controlled. The tendons, the nerves, and the deeper tissues are sutured to one another as far as is possible. As regards this point it may be said that most surgeons do not suture the several tissues to one another, but while no bad results may follow the adoption of this course, yet the time required for healing is undoubtedly lessened by a perfect apposition of like tissues. In the face of severe infections, the wound is left open and is packed until granulations appear, when secondary suture is made.

Fig. 2194.

This operation can also be performed by a posterior curved incision which exposes the malleoli. The incision is deepened and is carried through the tendo Achillis, after which the joint is opened, the malleoli are sawn, and the talus is extirpated. The operation is completed as in the operation by the anterior incision.

The after-treatment consists in absolute rest and elevation of the foot from three to five days in an immovable splint, which holds the foot at right angles to the leg. At the end of ten days any deviation of the foot can be corrected with ease.

The time required to obtain healing by first intention (5 cases) was from 28 to 48 days; for cases healing by second intention, 35 to 60 days (2 cases). If recurrences take place (2 cases) the time is naturally more extended, *i.e.* 84 to 397 days—an average of 210 days (Küttner). The mortality from the operation is nil.

The Final Result of Operation.—The shortening in the leg is usually from one centimeter to one and one-half centimeter, and that of the foot about one centimeter.

The function of the foot is good. It allows use all day and requires only an ordinary shoe.

The pendulum motion [illegible] the forefoot gives elasticity to the gait, [illegible] in artificial limbs.

The taloastragaloid excision is to be preferred to amputation, either Pirogoff's or Syme's, because it preserves the foot. It is preferable to the Wladimiroff-Mikulicz excision because it [illegible] tion and requires no subsequent prosthetic apparatus.

Posterior Tarsectomy. When disease involves not only the ankle-joint but the mediotarsal and tarsal joints as well, one of three things must be done: either an extensive atypical resection (Kümmell and Cramer), or a Wladimiroff-Mikulicz [illegible], or an amputation at or just above the ankle-joint.

A priori, it may be thought that removal of the calcaneus, talus, tarsal bones, the malleoli, and the articular surface of the tibia gives a bad functional result. This is not the case, however (Cramer[19]). The extensive removal of these bones, leaving a foot formed of a part of the tarsus, the metatarsus, and phalanges, gives a better result than the equinus position of the foot seen in the Wladimiroff-Mikulicz excision. It is true that the foot is shortened, but a foot with a sole is better than the equinus of the Mikulicz operation, because a movable foot is obtained and because the pressure-bearing surface is a natural one and greater in area than is obtained by the Mikulicz excision.

Indications.—Tuberculosis involving the ankle-joint, the calcaneus, talus, and tarsal bones, with fistulæ. In children and in young adults the operation is indicated. In adults who have tuberculosis elsewhere and are not holding their own against the disease, and in the old and anemic, amputation is preferable. No matter whether the fistulæ are upon the dorsum or upon the plantar surface of the foot, the operation with the dorsal incision is equally indicated.

The incision for exposure of the bones is similar to that used in the P. Bruns method. The removal of the talus is similarly carried out; after which the bones of the tarsus are removed *en masse*, as is recommended in the Bruns method. This removal of the tarsus is often complete, so that the section of the bones includes the bases of the metatarsal bones. The lower ends of the tibia and fibula are removed with a transverse section, unless the calcaneus can be partly saved, when the action is similar in shape to that recommended in the preceding excision. No matter how little of the calcaneus is saved, the resulting shortening and the functional result are much improved. After removal of the diseased bone the bases of the metatarsal or tarsal bones are apposed to the anterior surface of the lower end of the tibia, where they are fastened with sutures if possible. In Kümmell's first case, in which two and one-half centimeters of the tibia and fibula and all the tarsal bones were removed, the resulting shortening was about three centimeters. In two of Cramer's cases the resulting shortening was less.

After-treatment.—Frequently the large cavity after extensive removal of the bones cannot be closed, and must be packed with [illegible] open wound because of the presence of fistulæ. The cavity left between the tarsus and the tibia and fibula closes rather quickly. The soft parts of the planta pedis draw up between these bones and a pillow is formed under the tibia. The time required for this is usually two months. During this time the wound is dressed as required, and the proper position of the forefoot in its relation to the tibia is maintained by appropriate right-angled splints.

The results of this operation show that the gait is elastic and not "halting," as is the [illegible]

equinus position of the foot after a Wladimiroff-Mikulicz excision, or the amputations or disarticulations. This elastic gait is due to the pseudarthrosis between the tibia and fibula, or the calcaneus, and the forefoot. Another advantage claimed for this procedure is to be found in the fact that prosthetic apparatus will not be needed after the cure. Six cases reported by Cramer gave two cures in children of three and four years of age. Two cases of adults of ten and twenty years of age were still under treatment at three and four months. Two cases died of generalized tuberculosis following operation.

When the disease is of the same extent as would lead one to perform the foregoing operation, while at the same time the greater part of the heel is the seat of destructive disease and of fistulæ, the resectio tarsea totalis of Wladimiroff-Mikulicz may be considered.

The indications for this procedure are: (1) Caries of the talus, calcaneus, and tarsus (Mikulicz); (2) extensive loss of the tissues of the heel (Mikulicz); (3) injuries destroying the heel (Mikulicz); (4) new growths involving the bone (calcaneus) or tissues of the heel (Schliffosowsky and Wahle); (5) to increase the length of the extremity, as occurs in infantile paralysis (Caselli); (6) for paralytic equinovarus (Bruns).

The object of the operation is to secure an artificial pes equinus. The toes and metatarsus are preserved and are apposed, in a vertical plane, to the tibia and fibula. The patient walks upon the heads of the metatarsal bones with the toes bent at right angles to the leg. The operation was first performed by Wladimiroff in 1871 and by Mikulicz in 1880.

Complete Tarsectomy (Resectio Tarsea Totalis).—An Esmarch bandage is applied. The patient is placed upon the abdomen with the foot extended. Just in front of the tuberosity of the scaphoid bone, upon the inner side of the foot, there is made an incision which passes transversely across the planta pedis to a point just behind the tuberosity of the fifth metatarsal bone. From each extremity of this incision, upon each side, an incision is carried upward and backward to the malleolus. The extremities of the

Fig. 2195.

latter incision upon the malleoli are now united by a transverse incision across the posterior surface of the leg. When the bones of the leg must be denuded at a higher level than is usual, the lateral incisions must be carried beyond the malleoli (Fig. 2195). All incisions pass directly down to the bones, dividing the muscles, tendons, nerves, and arteries. The posterior capsule of the ankle-joint is divided, together with the posterior, middle, and anterior fasciculi of its lateral ligaments.

The foot is now thrown in dorsal flexion, and the talus and calcaneus are carefully separated from the soft parts of the dorsum of the foot until the mediotarsal joints are reached. Here these bones are separated from the cuboid and navicular, and are removed with the heel flap. The lower ends of the tibia and fibula are now sawn across. The cuboid and scaphoid bones are likewise sawn transversely (Fig. 2196).

The Esmarch bandage is removed and the arteries are tied. When hemorrhage is completely stopped, the cuboid and scaphoid bones are apposed to the

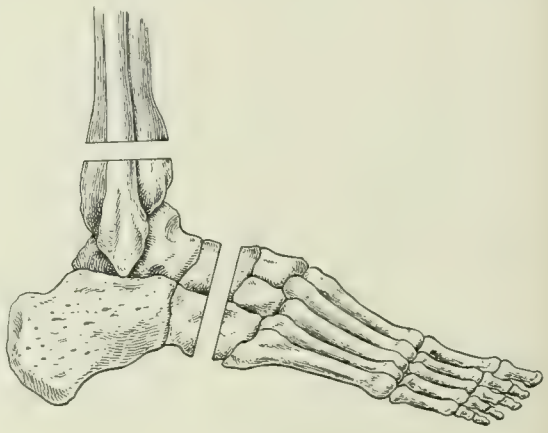

Fig. 2196.

tibia and fibula and are retained in position by chromicized catgut sutures. The wound is now closed with deep catgut sutures and over the aseptic dressing is placed an immovable plaster dressing holding the parts firmly.

Sometimes, in placing the bones in apposition, the folding of the anterior bridge of soft tissues displaces the forefoot. When this occurs, the bridge of tissue must be folded and retained by a few mattress sutures.

The after-treatment consists in elevating the foot and retaining this position from three to five days; after this it may be lowered. In from six weeks to two months the union is complete. The lengthening of the limb is usually one and one-half centimeters, which can be easily overcome by a heel upon the opposite foot. Fig. 2197 shows the foot healed.

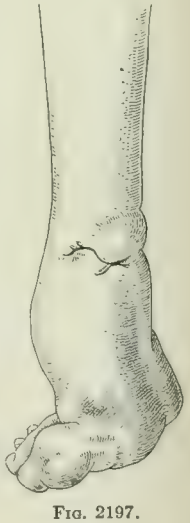

Fig. 2197.

Kohlhaas has collected seventy-three cases of this operation with one death from pyemia and one requiring amputation for gangrene. Several cases presented localized areas of gangrene, but did not require other than simple treatment. Three cases failed to have a firm union between the bones of the leg and foot and required subsequent operations. Fifty-six cases gave good results and required no extra prosthetic apparatus or shoe. Nine cases gave moderate results and required special prosthetic shoes.

To avoid the division of the posterior tibial artery and nerve, and the disturbances in nutrition and the gangrene which may result therefrom, Lotheisen, P. Bruns, and Ollier devised various modifications in the incisions. Lotheisen's incision is as follows: The patient lies upon the back. The extremity is

raised and the foot is dorsally flexed. Upon the outer surface an incision, commencing one and one-half centimeters above the attachment of the tendo Achillis and between the fibula and the tendon, is carried obliquely forward and downward below the malleolus, ending two centimeters behind the tuberosity of the fifth metatarsal bone (Fig. 2198). Upon the inner side a similarly placed incision is made, beginning above upon the same level and to the inner side of the tendo Achillis, descending forward behind the internal malleolus, and ending just in front of

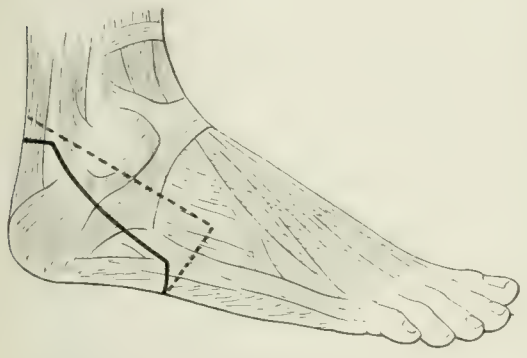

Fig. 2198.

the tuber calcanei (Fig. 2199). The extremities of these lateral incisions are united across the sole by an oblique incision (Fig. 2200) and across the leg by a horizontal one. The enucleation of the talus and the sawing across the tarsus and the bones of the leg are accomplished as in the former method. A very similar method was described by Jaboulay and Lagaite,[20] but it offers no advantages over the above.

To obtain the same result, P. Bruns has recommended strongly the simple median posterior incision, especially in cases in which the heel is intact and free from ulceration. Bruns' incision begins on the posterior surface of the leg, four fingers' breadth

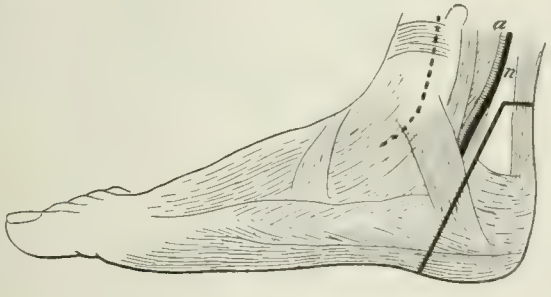

Fig. 2199.

above the tubercles of the calcaneus, passes downward over the center of the heel and to the center of the sole of the foot. This incision extends immediately down to the bones. The talus and the calcaneus are removed subperiosteally after opening the ankle-joint. The bones are sawn and apposed and held by suture.

Ollier has described a similar incision, but he had not performed it upon the living subject at the time when Bruns used his incision.

Of the incisions used for the total tarsectomy, none seems to meet the surgical requirements so well as Lotheisen's, which avoids injury to the posterior tibial artery and nerve and allows the tissues of the leg and sole of the foot to be easily apposed and sutured one to another. In cases of paralytic equinus or equino-talus with extreme shortening, the posterior incision of Bruns [illegible] has given as good results as the methods of Lotheisen and Mikulicz. In this particular class of cases the objections to be raised against the [illegible] subperiosteal enucleation of the [illegible] and the projecting mass of the heel when the parts are opposed, do not hold as they do in [illegible]

It may be said with truth that the total [illegible] (Wladimiroff-Mikulicz and the extensive [illegible] of Kümmell will scarcely appeal to many [illegible] when they compare the time spent in obtaining these results, the extent of the procedure, and the drain upon an already worn-out subject. An amputation (Syme's, Pirogoff's, Gritti's especially the first), with the rapid healing and the practical prosthetic appliances made in this country, will cause most surgeons to advise amputation whenever the patient can obtain an artificial limb. Only in the very poor and in those of moderate age and good health (especially such as have congenital and paralytic deformities or injuries) will the extensive procedures of Kümmell and Mikulicz be adopted. On the contrary, the anterior and posterior tarsectomies of Bardenheuer and Bruns give such excellent feet after operation that no question can be raised as to their advisability in suitable cases and their superiority to amputations.

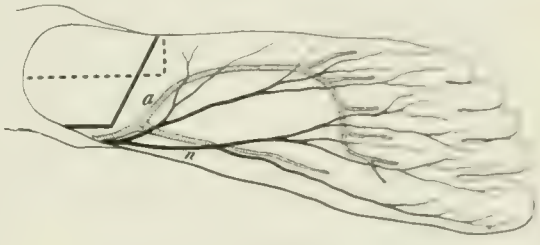

Fig. 2200.

Excision of the Ankle-joint.—This operation was first performed by Moreau in 1792. Subsequently, owing to the complicated character of the joint, the presence of tendons and sheaths in the immediate neighborhood and the relapses following operation, surgeons gave up the method and resorted to amputations. Better methods of approach, more complete removal of the disease, and the aseptic treatment of the wound have so lowered the mortality that amputation now presents no advantage in this respect. At the same time the patient is left with a foot which is more useful and esthetically better than the stump of an amputation.

Partial excisions are those which remove the whole or a part of the articular surfaces of the tibia, the fibula, or the talus; complete excisions remove all of these surfaces.

The talocrural articulation is approachable from the sides. In front, it is covered by the tibialis anticus, the extensor longus digitorum and proprius hallucis and the peroneus tertius, the nerves, and the anterior tibial artery. Behind it is covered by the tendo Achillis in the center, and upon either side of this by the peroneal tendons, the tibialis posticus, flexor longus digitorum, longus hallucis, together with the posterior tibial nerve and artery. For this reason the lateral surfaces are much used for incisions. The ankle-joint is a powerful joint because of its [illegible] reason of its ligaments. The ligaments uniting the malleoli to the tarsus are strong. Those for the internal surface are three: the deltoid uniting the malleolus with the sustentaculum tali, the anterior uniting it with the scaphoid, and the posterior uniting it with the talus. Those for the external

surface are: the anterior, uniting the external malleolus with the talus; the middle, uniting it with the calcaneus; the posterior, uniting it with the talus. The anterior and posterior ligaments are thin and insignificant. The synovial membrane lines the capsule, and extends beyond the limits of the articulation both in front and behind. At the sides it is delimited by the articular surfaces.

The epiphysis of the tibia includes the lower end and the internal malleolus. It unites with the diaphysis at about the nineteenth year. The epiphysis of the fibula unites with the diaphysis at about the twenty-first year. The outlines of the malleolus are easily felt and seen. The head of the astragalus is felt in full extension of the foot. The ankle-joint lies opposite a transverse horizontal line one and one-fourth centimeters above the tip of the internal malleolus.

The Indications.—Partial excisions are indicated in gunshot wounds; in compound fractures and in dislocations when the nerves and vessels are intact; and in suppuration following injury and infection when this excision removes and drains the focus of infection. For tuberculosis in childhood, expectant treatment and iodoform injections may precede the partial excisions, *i.e.* the erosions or the arthrectomies, but delay must not be too long before resorting to the excision. In adults formal excisions are used. In older people, with other tuberculous foci, amputation is preferable to excisions. As a general rule, when tuberculosis is apparently primary in the joint, excision is to be preferred. When the ankle-joint is involved, secondarily to other well-defined deposits in the lungs and elsewhere, amputation is preferable.

Fig. 2201.

There are about thirty-six incisions which have been recommended for entering this joint. All surfaces of the joint have been made use of to gain an entrance. Even the sole of the foot, *i.e.* the heel, has been included in the incisions. No incision has so many advantages as that of Lauenstein. This incision resembles Kocher's incision, but it gives a better exposure of the posterior angle of the ankle-joint and of the neighborhood of the internal malleolus. Kocher's incision was an improvement upon Reverdin's. Lauenstein's is an improvement upon Kocher's.

The method is as follows: An Esmarch's bandage is applied. The foot is placed upon its inner side. An incision is begun upon the fibula at the point where the fibula appears between the peroneus brevis and the peroneus tertius muscles. (Fig. 2201, *a*.) This incision is carried through the skin to the tip of the malleolus, where it bends forward in a broad curve to opposite the taloscaphoid joint, passing over the heads of the extensor brevis digitorum and exposing the tendons of the peroneus tertius. It is now deepened, exposing the periosteum of the fibula, the anterior fasciculus of the lateral ligament, and the capsule of the ankle-joint. Upon the posterior border of the fibula the sheath of the peroneal tendons is opened, and the tendons are retracted posteriorly. The knife now separates from the periosteum of the tibia and fibula the muscular fibers of the peronei and the flexor longus hallucis until one-half the transverse diameter of the fibula is freed.

The retractors used upon these structures are now removed and are inserted into the anterior flap. The ankle-joint is opened in front of the external malleolus and the blunt retractor is inserted, lifting and protecting the capsule and the superjacent

Fig. 2202.—Lauenstein's Method. Parts exposed ready for excision. *t*, Talus; *pt*, peroneal tendons; *em*, external malleolus.

tissues. The upper and lower attachments of the capsule to the talus and to the tibia are severed until the median line of the tibia and the talus are both reached. The foot is now supinated and the three fasciculi of the external lateral ligament are divided. When they have been divided, if the foot be placed in the equinus position and be gently thrown into supination, it will turn upon the internal malleolus as an axis, provided the tissues in front and behind the joint have been freed to a point beyond the median line of the joint. With a little force the foot can be completely inverted, so that the planta pedis looks upward and the articular surfaces of the talus and tibia are upon the same plane, separated by the internal malleolus (Fig. 2202). By means of blunt hooks every part of the articular surfaces of the talus, tibia, and fibula can be reached; every pocket

of the synovial cavity, including the inferior tibiofibular prolongation and the posterior surface of the synovial membrane, the sheaths of the tendons of the tibialis posticus, flexor longus digitorum and hallucis, as well as the bursa and fat in front of the tendo Achillis. When these are inspected and all foci of disease have been removed by curettage or excision, the foot is easily pronated and thrown into proper position. The only structures injured are the vena saphena parva and the arteria perforans peronea. The advantage of the incision over Kocher's is that it allows a greater stretching of the borders of the incision and an easier dislocation of the foot. Moreover it parallels the sheaths of the tendons and permits a surgical treatment of them when involved. If in operating by this method it becomes necessary to remove the talus, it can be accomplished easily by dividing its ligaments which are exposed to view. Indeed, the method renders the extirpation of the talus a very easy matter.

If disease involves the mediotarsal and the talocrural joints together with the neighboring bones, or if this is only recognized by the operator after he has entered the talocrural joint by the Lauenstein incision, the suggestion of Heidenhain[21] may be adopted for the treatment of the case. This suggestion consists in continuing the lower end of the Lauenstein incision across the dorsum of the foot below the mediotarsal joint and dividing the tendons of the peroneus tertius and extensor longus digitorum but preserving if possible the tibialis anticus and extensor proprius hallucis. This incision gives all the advantages of the Lauenstein and P. Bruns excisions, and opens to view for easy attack the mediotarsal articulation.

Again, if the talocalcanean or the taloscaphoid joint alone is involved, we can adopt the following suggestion of Lauenstein and approach these parts with the same skin incision: Instead of opening the talocrural articulation, we divide the calcaneofibular division of the external lateral ligament, and then, passing a thin knife into the sinus tarsi, carry it backward and inward to the sustentaculum tali, dividing the interosseous ligament. After this division the anterior talocalcanean capsular ligament is made tense by everting the calcaneus and is divided. This is followed by division of the muscular fibers of the extensor brevis digitorum and the taloscaphoid ligaments upon the outer and superior surfaces of this joint. If strong supination is now made upon the foot, the calcaneus will be luxated or rotated upon its inner side over the malleolus internus. In this manner the talocalcanean and the talonavicular joints may be exposed without opening the ankle-joint. During the luxation of the calcaneus the peroneus tendons are retracted posteriorly and do not obstruct the field. From this position of the foot the talus may be easily removed by division of its lateral ligaments. In extensive disease in this region the Lauenstein incision permits an entrance into the talocrural articulation, and if desired allows an exposure of the mediotarsal and talocalcanean joints with removal of the talus. The mediotarsal and talocalcanean articulations may be entered first, and if suspicion exists as to an involvement of the talocrural articulation this may be exposed by removal of the talus. This incision gives the best approach to the ankle-joint. It allows of such modifications as will insure successful results in spite of unsuspected foci of disease, since through one incision the talocrural, the talocalcanean, and the mediotarsal joints can be approached and the talus removed. In a pure resection of the ankle-joint the synovial membranes and the articular surfaces of the talus and of the tibia and fibula are removed, their shape being preserved as far as possible. For this reason the section of the tibia and fibula is usually made concave from side to side, while that of the talus is made convex. If the talus is removed for purposes of disease, this concavity in the tibia and fibula is made so as to fit the convexity of the talus. The anterior border of the tibia rests upon the prepared [illegible] but little of the articular surface of the talus remains, it is best to shape the tibia so that the tibia may rest upon the [illegible]. It is well to suture the scaphoid, tibia, fibula, and calcaneus together with two or three [illegible] catgut sutures. It is rare that a single artery requires ligature, and if any bleed excessively they will stop upon elevation of the limb. When it is possible to remove all tuberculous material, the wound is packed until healthy granulation tissue appears.

The after-treatment is a matter of [illegible]. When the wound is sewed up, the foot is elevated at an angle of forty-five degrees from three to five days, after which it is lowered. In this method the first dressing is made about the tenth day. Where wounds are packed, the foot is usually elevated for twenty-four to forty-eight hours, after which it is lowered. The dressings should be changed every two or three days.

A suitable splint is difficult to find. A splint which will maintain the foot at a right angle with the leg and will prevent lateral deviation of the foot is the one desired. Upon the whole, a plaster-of-Paris dressing properly and carefully applied is the best. This plaster-of-Paris dressing may be used alone or in conjunction with the McCormac splint. If it is applied alone, it is well to place this dressing within a Volkmann's posterior splint, where it will be held firmly. After two weeks treatment the other splints may be discarded and a splint plaster-of-Paris dressing will be sufficient until union is complete.

Results. The mortality, in the different classes of cases, was as follows: *For gunshot wounds* (45 cases) according to Culbertson, 26 per cent.; according to Otis (33 cases in the civil war), 29 per cent.; and, according to the same authority (150 cases from all sources) 33 per cent. *For injuries in civil practice* (152 cases) according to Culbertson, 12. per cent. *For disease* (124 cases) according to Culbertson, 8.06 per cent. for complete excision, and 6.55 per cent. for partial excision; while, according to Isler and Kappeler, it was almost nothing in cases of tuberculous disease.

Functional Results. Some say that a [illegible] joint is very rare, others, that it is unknown. Ankylosis is often obtained, and when it occurs the mediotarsal joint compensates in great measure for the stiffness in the ankle. In seventy-five per cent. of the cases recovery takes place with a useful limb, and in many instances, especially in the subperiosteal method, the nearthrosis is a remarkable one, giving a most useful joint (Langenbeck).

According to Isler the results of excision functionally are divided as follows: Very good, 40.8 per cent.; good, 26.8 per cent.; moderate, 7.6 per cent.; indefinite, 8 per cent.; bad, 6.2 per cent. In children the good results are more frequent than in adults, since the disease is usually less extensive.

Schmidt Monnard gives the good results as 74 per cent. for the first fifteen years of life. In Bardeleben's clinic good results were obtained in 81.2 per cent. of the cases. Karewski in [illegible] had [illegible] good [illegible] 2 deaths from scarlet fever and tuberculosis respectively, and 3 cases with recurrences.

Excision of the Fibula and Tibia. [illegible] removal) of the fibula and tibia is indicated for the same conditions as that of the radius and the ulna. When dealing with the fibula the special points to bear in mind are concerned with its extremities. Thus, at the upper extremity the superior tibiofibular joint communicates with the knee-joint in ten per cent. of cases (Lenoir, cited by Ashhurst), and the neck is crossed externally by the external

popliteal nerve. To avoid opening the joint the head of the bone should be left intact, if feasible. The nerve will not be harmed by the careful operator. The lower extremity, through the external malleolus, performs an important function in maintaining the astragalus in the tibiofibular mortise, and by its removal the foot is liable to become everted. Unless contraindicated, then, it is best to preserve the head above and the malleolus below by performing resection instead of excision. Even if one extremity alone can be preserved, it will act as a *nidus* with which an autogenous bone-graft may be contacted, with good prospect of the bone being reproduced. In subperiosteal excision in the young, also, especially after sequestrotomy where there is a good involucrum, again the bone may be reformed. These general remarks apply equally well to the tibia, the main difference being that while the fibula is a slender bone which is poorly developed in man, and one which plays no direct part in supporting the weight of the body, the tibia, on the other hand, is the mainstay of the leg.

Excision of the Fibula.—The incision for excision of the fibula is made posteriorly. It begins above at the superior tibiofibular joint, and taking as its guide the posterior limit of the peroneal compartment (which contains the peroneus longus and the peroneus brevis muscles), passes vertically downward to the ankle-joint. Dividing the skin, the superficial and the deep fascia, and avoiding the external popliteal nerve above and the peroneal artery below, it makes directly for the bone by passing above, between the peroneus longus before and the soleus behind, and below, between the peroneus longus and brevis before, and the flexor hallucis longus behind. Working subperiosteally with a sharp rugine, the bone is bared first circumferentially at its center, where it is divided. Each half is elevated from its bed and cleared of its periosteal envelope down to and into its respective joint, where disarticulation is performed. All layers are now ready to be approximated by sutures—the periosteal and periosteocapsular coverings are closed, the muscles quilted, and the edges of the deep fascia, the superficial fascia, and the skin apposed in order. Temporary drainage is instituted if indicated, and the limb put at rest on a splint.

The incision for *resection* (partial removal) of the fibula varies according to the part to be dealt with. The upper extremity is removed through a longitudinal incision, which begins one inch above the styloid process at the posterior border of the tendon of the biceps femoris muscle, and passes vertically downward between the peroneus longus muscle externally and the soleus internally as far as is necessary, thus leaving the external popliteal nerve to the outer side. As much as the upper half of the bone may be removed through this incision. If not contraindicated, as much of the head as is possible should be spared, for reasons mentioned above. In resecting the lower half, it suffices to employ an anteroexternal incision, which passes just in front of the peroneal muscular compartment. Resection of the lower extremity is dealt with under resection of the ankle-joint.

Excision of the Tibia.—The incision for excision of the tibia is a simple one. Beginning above at the knee-joint, it follows downward a line placed just anterior to the internal border of the bone, and terminates at the ankle-joint. In passing down to the bone, the incision runs behind the tendons of the sartorius, the gracilis, and the semitendinosus muscles above. Below, the internal saphenous vein with its accompanying nerve should be isolated and retracted. After this the tibia is dealt with in the same manner as in excision of the fibula and of other long bones. (Fig. 2203, *d*.)

The incision for *resection* of the tibia is made in the same line as in that for excision, its length being sufficient to fulfil indications. The hiatus left after resection may readily be spanned by an autogenous transplant, which acts as a scaffolding for reformation of the portion removed. Special resections of the tibia that are commonly performed are trephining in the case of Brodie's abscess, which may involve the upper or the lower extremity, and the removal of a transplant from the tibial crest. In the latter operation, a longitudinal incision of sufficient length is made over the anterior border of the tibia, and the crest of the shin exposed. Transverse saw cuts are made at the upper and the lower limits of the graft, the length of which varies in each case. This prevents splitting of the transplant in a wrong direction. The section of bone is now removed by a curved Buck chisel or a Butcher saw, which may be guided by Murphy's retractor-guide. The periosteum may or may not be preserved. Aside from the length, the size of the transplant is usually that of the adult index or middle finger, about $\frac{3}{8} \times \frac{1}{2} \times \frac{5}{8}$ inch. The defect in the tibia fills in rapidly in from four to six weeks. The indications for and general remarks concerning excision and resection of the tibia have been dealt with under "Excision of the Fibula and Tibia."

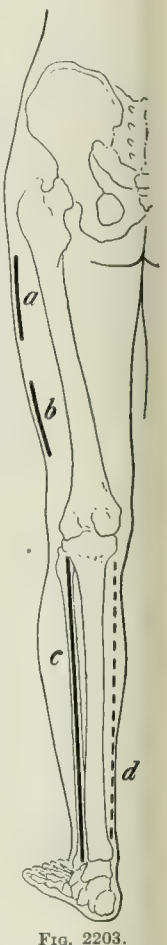

Fig. 2203.

Excision of the Knee-joint.—In 1762 Filkin of Norwich attempted a partial excision of this joint. Park in 1781, and Moreau and Roux before 1820, operated, performing a complete excision, but the unfortunate results obtained by their imitators deterred many surgeons until W. Fergusson in 1850 restored the operation. From this time the operation has been practised extensively and remarkably good results are now obtained in every country.

The cases operated upon are divided into those which are typically excised and those which are atypically treated. The typical operation consists in the extirpation of the synovial membrane and the removal of the bones intra- or extra-epiphyseally. The atypical one consists in the extirpation of the synovial membrane without removal of the bone except where diseased. This is the arthrectomy of Volkmann[20] and the erasion of Wright.[21]

The atypical operation is undoubtedly the operation for children, since in eighteen per cent. of the cases in which the bones were not at all or only very slightly involved, movable joints have been obtained. In the second place, no shortening, at least no more than follows conservative methods, takes place (Maudry).

A comparison of these atypical cases with the intraepiphyseal resections (Hoffa) shows that the only real advantage is the possibility of obtaining in the most favorable cases a movable joint, and since this occurred in nearly eighteen per cent. of the seventy cases collected (Maudry), it offers a substantial advantage in favor of the atypical operation. The disadvantages of the atypical method consist (1) in the liability of leaving beneath the articular cartilages foci of disease, (2) in the greater tendency to contracture of the flexor muscles. The first disadvantage is more apparent than real in the cases of children, because in making an intraepiphyseal

section one must cut the bone below the level of the articular cartilage. "Every bone section in children must be surrounded by a line of articular cartilage to be certainly intraepiphyseal" (König). This section is so thin that foci may not be revealed by it, just as when the articular cartilage is present. The advantage which belongs to the typical intraepiphyseal method, and which does not belong to the atypical method, is the firmer union which takes place between the bones and the slighter tendency to deformity. The lack of this advantage in the atypical method is compensated for by prolonged mechanical after-treatment.

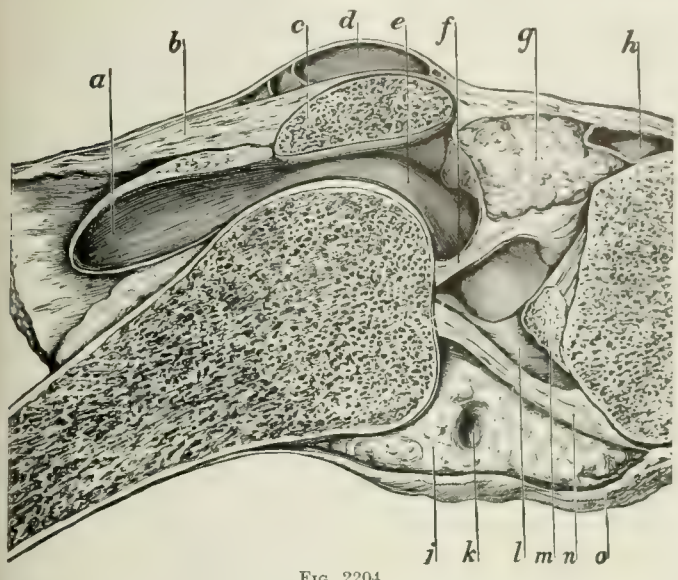

Fig. 2204.

When the bones are but slightly involved and the synovial membrane is the principal seat of disease, the atypical operation is indicated because of the eighteen per cent. of movable joints which have been secured by its employment. If in addition to the synovial membrane the bones are much involved, the intra- or extraepiphyseal excision is indicated, according to the extent of disease in the bones. This is because of the firmer ankylosis in the extended position which is obtained by the section of the bones, and also because it is not possible to obtain motion on account of the destruction of the articular cartilages. It is to be remembered that in excisions shortening is greater if done before than after the fourteenth year.

Indications.—For disease: 1. Tuberculosis. Excision in these cases should be performed (*a*) in all cases in which the articular cartilage is found eroded, whether suppuration is present or not; (*b*) in cases with backward dislocation of the tibia; (*c*) in cases that have lasted over six months, in which the expectant treatment has been tried and has failed and in which the disease is in all probability an epiphyseal osteitis; (*d*) in cases of synovial tuberculosis which has extended over the articular cartilages. In the child before fifteen years, this operation affects the growth of the limb. In adults of twenty years and over, the length of the limb need not be considered, but the conditions of the viscera and the general health become important considerations. In all cases: The presence of amyloid degeneration; tuberculous disease of the lungs and other viscera; great emaciation and extensive involvement of the soft parts about a joint demand amputation rather than excision. 2. Chronic arthritis, with caries of the bones. 3. Chronic osteoarthritis in a *single* joint in middle life. 4. Ankylosis of the knee in a bad position after osteotomy has failed. 5. In irritable paralysis for the production of ankylosis. In these cases the excision is usually a complete one.

For injury: Gun-shot wounds and other compound and complicated injuries. In these cases the excision is usually partial rather than complete.

Anatomy. The axis of the femur [illegible] inward at the knee. That of the tibia is straight, *i.e.* in the axis of the body. The joint obtains no strength from the shape of the bones. It derives its strength from its crucial and posterior ligaments rather than from its lateral and anterior ligaments. The cavity of the synovial membrane is extensive and the bursæ about the joint are numerous. Of these bursæ, that between the inner condyle, the semimembranosus, and the inner head of the gastrocnemius communicates with the joint. The bursa beneath the tendon of the popliteus communicates with both the knee-joint and the superior tibiofibular articulation. In like manner, the bursa beneath the vasti and the rectus communicates in eighty per cent. of the cases with the joint. The popliteal artery and vein are quite closely associated with the ligament of Winslow, and care must be taken in dissecting out diseased tissue in this region in order to avoid injuring them (Fig. 2204). The articular arteries should if possible be avoided, but, if they cannot be avoided, they should be tied before closing the wound. The superior articular arteries are situated just above the condyles, while the inferior pass beneath their respective lateral ligaments, the internal below the tibial tuberosity, the external above the head of the fibula. It is to be remembered that the

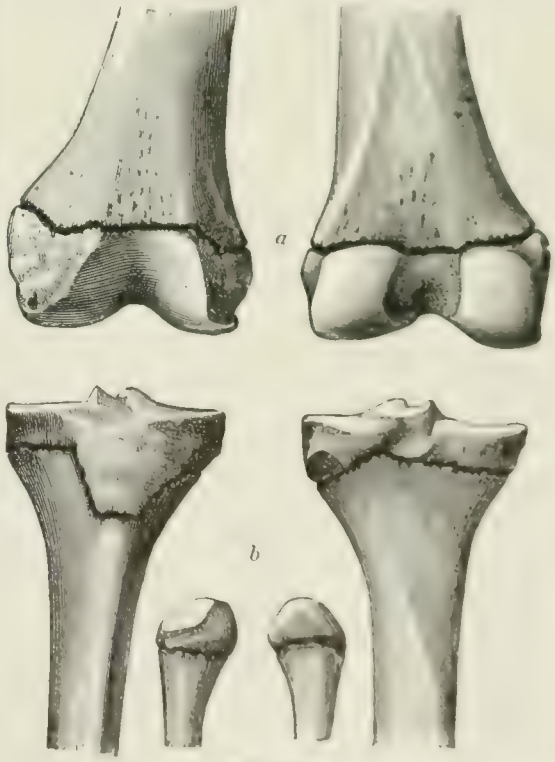

Fig. 2205.

upper limit of the femoral epiphysis is represented by a line passing across the femur at the tubercle of the adductor magnus. (Fig. 2205, *a,a.*) This epiphyseal line is intracapsular. The tibial epiphysis is marked at the sides by a line just including the fibular articular surface, and the depression for the semimembranosus tendon behind this line just includes the tuberosities. In front, the epiphysis descends to the lower margin of the tubercle. This epiphyseal line is extracapsular. The femoral epiphysis joins the shaft at twenty, the tibial at twenty-one years. (Fig. (2205, *b,b*). In a child, scarcely more than 1 centimeter of the tibia and 1.5 centimeters of the femur can be removed without compromising the growth of the limb. After puberty (seventeen years), 1.5 centimeters of the tibia and 2 centimeters of the femur may be removed (Farabœuf). Hoffa says that (1) in one case the removal of both epiphyses at the end of ten years gave 25.5 centimeters shortening; (2) in one case at the end of two years there was 10 centimeters shortening; (3) the loss of the femoral epiphysis alone in one case gave 17 centimeters shortening at the expiration of six years; (4) the loss of the tibial epiphysis alone in two cases gave respectively 15.5 and 6 centimeters shortening in six years; *i.e.* an average of 10.7 centimeters. Petersen, in a child of six years of age, at six years from the time of the excision, found a shortening in the femur of 10.2 centimeters, of which 8.5 centimeters was due to the loss of the lower femoral epiphysis. In the tibia, there was 5 centimeters shortening, of which 3 centimeters was due to the loss of the upper tibial epiphysis.

It is to be remembered that when the knee is flexed the extension of the synovial membrane above the femur and beneath the quadriceps femoris tendon scarcely reaches above the articular cartilage of the femur; when the leg is extended, the same rises to a much greater distance. (Fig. 2204, *h.*)

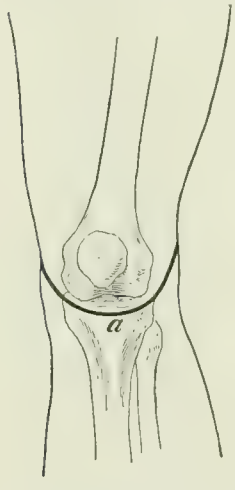

Fig. 2206.

Incisions.—Many incisions have been recommended for this operation, and of the great number variously used by Park, Moreau, Fergusson, Mackensie, Golding-Bird, Volkmann, Langenbeck, Ollier, Textor, Sanson, and Bégin, none seems to be as advantageous as that recommended by Mackensie, Farabœuf, Erichsen, Ashhurst, and Kocher, *i.e.* the transverse curved incisions of Textor.

The object of this resection is usually to produce ankylosis without considerable shortening, *i.e.* without shortening over ten centimeters, which can be corrected by a high shoe and by the inclination of the pelvis. For this reason only such incisions are useful which will expose all parts of the joint and enable one accurately to remove only the diseased tissue. To obtain this exposure, the transverse incision is preferable to the longitudinal. The longitudinal incisions were designed to save the patella and to aid in producing mobile joints, but the best results are usually those in which ankylosis exists, and in these the patella is not necessary.

The operation by the longitudinal incision is difficult and tedious, and in disease fails to expose all parts of the synovial membrane. For this reason alone, in disease, the transverse is to be preferred to the longitudinal incision. In some few cases of injury with partial excision of the bones, the longitudinal incision is indicated, but in the vast majority of cases no incision is so satisfactory as the transverse.

Method of Operation.—Typical excision. The patient lies upon the back, with the leg at the end of the table, so that in flexion at the knee the foot may rest on the table. The surgeon stands upon the side to be operated. One assistant, opposite the surgeon, manages the thigh, another manages the leg. A third manages the sponging, etc. During the skin incision, the leg is held firmly flexed upon the thigh. The incision, at first involving the skin and subcutaneous tissue, passes from the condyle of one side to that of the other in a broad curve, which crosses the ligamentum patellæ midway between the tubercle of the tibia and the lower margin of the patella (Fig. 2206). This incision avoids injuring the saphena magna vein and the internal saphenous nerve, as it approaches the internal condyle. The flap marked out is dissected from the capsule and the patella and is reflected above the upper border of the patella. An oval-shaped piece of the anterior capsule, including the patella and the synovial membrane, is now excised by two incisions passing from the posterior borders of each lateral ligament across the upper and lower extremities of the patella. With the removal of this piece the joint is fully exposed. This is the method of procedure in non-tuberculous processes, in injuries, and in deformities, where the ultimate aim is ankylosis. In tuberculosis Kocher's suggestion is the proper one. After reflection of the skin and subcutaneous tissue as above, an incision is carried through the lateral ligaments, the fascia of the vasti muscles, and the quadriceps tendon in a curve above the patella down to but not through the synovial membrane. The flap above is cleared from the synovial membrane until the attachment of the latter to the femoral articular cartilage is reached. In like manner, the flap below is separated from the synovial membrane as far as the latter's attachment to the tibia, the ligamentum patellæ being divided at its attachment to the patella. Thus the tuberculous synovial membrane, together with the patella, is removed in one piece. Whichever way one has proceeded the joint is now open and the crucial ligaments are seen. With increased flexion by the assistant, the crucial ligaments are rendered more evident and the division of the anterior and then the posterior close to the femur is made. The leg now hangs loosely upon the femur. It is flexed to a right angle, with the foot resting upon the table and the femur raised. In this position the femur is cleared of its soft parts—including the periosteum if desired and if indicated by the local condition—up to the line of intended section. The popliteal space is protected by a broad retractor and the bone is sawed with a solid-bladed saw. The plane of section is sagitally at right angles to the axis of the femur. Frontally it is parallel to the plane of the articular surfaces of the condyles. This is in "a plane which, as regards the axis of the femur, is oblique from behind forward, from below upward, and from within outward" (Ashhurst). The importance of a correct line of section of the femoral condyles cannot be overemphasized.

The tibia is now pulled forward while the foot still rests upon the table. The popliteal tissues are put upon the stretch and brought into a lower plane than the articular surface of the tibia. This is exaggerated by freeing the tibia posteriorly where the ligament of Winslow is attached. The tibia is now held firmly in this position and is cleared of all tissues to the line of bone section. It is sawed at right angles to the axis of its shaft. The section in the bones is in the young always within the epiphyseal line; in the adult, the section is made as often extraepiphyseally.

The tissues in the popliteal space are in no danger, since they are placed at a lower level than the bone section, owing to the traction upon the leg held in the vertical position. In non-tuberculous cases and in cases of deformity, the synovial membrane is now dissected from the bones and the capsule. It is usual to begin with that above the femur and beneath the

quadriceps tendon. This with the bursa is removed as a continuous membrane and can in almost all instances, except where disease has advanced beyond its limits, be removed without further incisions. In the more extensive cases a vertical incision must be added to the transverse one. So infrequently is this the case and so thoroughly can one, by means of this additional incision, approach without excessive injury the space beneath the vasti and quadriceps muscles, that all incisions with their curve upward (Hahn), which are designed more fully to expose this region, may be rejected.

The advantages obtained by this method of procedure are, taken all in all, more than those derived from incisions destined to expose the space beneath the quadriceps muscle at the expense of the rest. The areas next in importance are the immediate neighborhood of the tibia and the popliteal space. The synovial membrane about the sides and front of the tibia and the adjacent synovial membrane are now removed, including the bursa beneath the ligamentum patellæ. At this stage an assistant places his hand in the angle formed by the tibia and femur, and by pushing apart these bones puts the tissues in the popliteal space upon the stretch, which renders the removal of the bursæ already referred to an easier matter than when their tissue is not firmly stretched. If removal of the disease in the rest of this region is now undertaken and if sinuses exist here, it is best to locate first the position of the artery and vein and then to proceed to the removal of the diseased parts. Providing the excision has been an extensive one, it is well at this time to remove the Esmarch bandage and to tie the articular, the anastomotica magna, and the recurrent tibial arteries. All hemorrhage from the bones stops when they are apposed. If the operation has not been so extensive, then in all probability these vessels have not been cut or at most only one or two of them; under these circumstances it is not necessary to remove the Esmarch bandage, but to rely entirely upon the firm dressing and the elevation of the limb for controlling the hemorrhage. Two openings are now drilled in the femur and in the tibia, and through them are passed large-sized chromicized catgut sutures, which, after the popliteal tissues are held away from the bones and after the bones are apposed, are tied tightly. These stitches are not for the purpose of holding the bones after the operation is completed but rather at the time of applying the primary dressing. They enable the assistants to feel that the bones remain *in situ* and have not slipped from their original position. Complete reliance is placed upon the dressing for holding the bones in position. This is true of adults but in the case of children the employment of metallic sutures like silver wire, as originally suggested by Gordon Buck may be occasionally advantageous.

If large sections of the femur and tibia have been removed a piece of the circumference of the femur may be sawed out and transplanted to the space between the tibia and femur, as in a flap operation upon the soft parts. Sykow was successful in one case in preventing shortening and in having the consolidation of the limb perfect in three months. His success may well be imitated in suitable cases.

After the suture of the bones the capsule, the ligamentum patellæ, and the tendon of the quadriceps femoris are united with catgut. For the tendon and the ligament use chromicized catgut, which lasts from fourteen to twenty days; for the capsule, use simple catgut. The skin is sutured also with catgut or silkworm gut.

Drainage is established only to give exit to the excess of blood, so that the employment of Maas' method, or the insertion of rubber tissue into the incision wound, is quite sufficient.

In operating upon joints which are flexed, it is best to straighten them as much as possible before operating. In this way one avoids [illegible] at the same time to remove [illegible] in the popliteal space [illegible] This stretching tends to displace the fragments [illegible] by closing the [illegible] foot and leg. Tenotomy of the hamstring tendons may be done with profit [illegible] excision, in certain badly flexed knees.

Hartley's method of dressing [illegible] most satisfactory. It consists in applying an even and not bulky dressing of gauze [illegible] upper third of the thigh. [illegible] gauze dressing eight to twelve [illegible] splints cut in strips two to three centimeters wide and boiled until they are not only aseptic but perfectly pliable, are applied over the joint and are bandaged quite loosely in position. Over this is placed a sufficient cotton dressing which is fixed with plaster-of-Paris bandages. This plaster-of-Paris is not thick; it is scarcely more than two bandages thick except where it covers the knee. It extends from the toes to the upper third of the thigh. The limb is now placed in a Volkmann's splint, which can be suspended or raised in bed to the required height. No dressing or splint holds the knee so firmly and without undue pressure as does this combination. The wood splints or strips, placed directly over an evenly applied gauze dressing, can be trusted, when they harden, to render slipping of the bone surfaces impossible. The plaster-of-Paris applied outside of the cotton and from the toes to the middle of the thigh holds the foot, leg, and thigh immovable, and exerts an even pressure upon all these parts. The Volkmann's splint protects and sustains the plaster-of-Paris dressing, which on this account need not consist of more than two thicknesses of bandage. This suffices for the immediate dressing, but fixation must be continued for a varying period after operation. Some have placed the period when ankylosis becomes complete at two months (Riedel), others at from six to eight months, and still others at one year (Hoffa). During this period the limb must be kept perfectly straight, and for this purpose plaster-of-Paris dressing is still used with perfect satisfaction. Windows can be made where necessary and the wound kept clean and healthy. The essentials of a good splint are absolute immobility of the limb and, in some instances, ready access to the wound. There seem to be no advantages in the Howse or Hodgson splints which are not found in the above plaster-of-Paris dressing. Almost all the splints employed have the disadvantage of being complex and difficult to adjust. After splints have been removed, a leather support is usually applied. In children a support should be worn for from two to three years.

Results.—The age of the patient is important. The results are best, for either injury or disease, between five and fourteen years. The fourteenth year is the best year of life for knee excision, all factors considered (Holmes). Esmarch had no deaths in 30 cases, Volkmann, no deaths in 20 cases. Hahn, Maas, and Schede have had similar results. In 1898 Napalkow reported 26 cases operated upon between seventeen and twenty-five years of age [illegible] deaths. These statistics for tuberculosis bring the mortality very low. The general mortality for all cases and under all conditions is at present about ten per cent. (Bothe.) The former high mortality of 7 per cent. for gunshot wounds, 40 per cent. for injury, and 30 per cent. for disease is being gradually reduced by a better selection of cases [illegible] technique.

The final results of excisions in children up to the fourteenth year show (Hoffa) that 6 per cent. of failures occur, most of which require amputation; that 7 per cent. die of tuberculosis in other organs at a subsequent period; that 58.47 per cent. have an ankylosis in the straight position, with neither genu

valgum nor genu varum; that 41.53 per cent. have a flexion contracture due (1) to a faulty position of the leg and thigh at the time of operation, (2) to contracture of the flexors and atrophy of the quadriceps femoris, and (3) to the weight transmitted through the limb in faulty position. All of these conditions are avoided by obtaining a bony ankylosis in the extended position before the limb is used. Eighty-seven per cent. of the cases were permanent cures (54 per cent. without subsequent fistulæ, 33 per cent. with fistulæ requiring from one to twenty-one months to cure). One hundred per cent. of the cases show some interference in the growth of the limb, yet in 92 per cent. this is not greater in the intraepiphyseal excisions than in the conservatively treated cases (*loc. cit.*, p. 794). In 8 per cent. of the cases measured by Bothe, lengthening had taken place. The final results in excisions in which the subjects are older and in which the operation is either intra- or extra-epiphyseal, in so far as the bone section is concerned, are: *In operations for tuberculous disease* (443 cases) (Bothe, *l. c.*). Healed and useful limbs, 67.4 per cent.; incompletely healed, 13.7 per cent.; amputated, 8.8 per cent.; useless, 17 per cent.; mortality, 10.1 per cent. *In operations for gunshot wounds.* Useful, 60 per cent.; required amputation, 24 per cent.; unknown, 16 per cent. *In operations for relief of deformity.* Perfect, 19.5 per cent.; useful, 68 per cent.; unknown, 13.5 per cent.

The Atypical Excision.—By this is meant the method employed by Wright under the name of erasion and by Volkmann under the name of arthrectomy. It is an operation in which the synovial membrane and bursæ are removed entire and in which the bone foci are gouged out, scraped out, or chiselled out, while all that is healthy is left intact. An operation of this kind in more favorable cases consists of a synovial extirpation with the gouging out of one or more small osseous foci; in the more extensive cases it consists of a nearly complete removal of the articular cartilage, *i.e.* of an almost typical excision.

The operative technique is usually carried out by a transverse incision through the skin, subcutaneous tissue, lateral ligaments and fibrous capsule, down to the synovial membrane; reflection of this flap upward, and extirpation of the synovial membrane as recommended by Kocher for typical excisions. It is now customary, after the crucial ligaments are divided and the menisci removed, to examine the bones carefully, in order to determine from the beginning whether a limited destruction of the articular cartilage will suffice, or whether this must be removed in greater part. It is at this stage that it is determined whether the operation is to be the erasion or the intraepiphyseal excision. Provided the former is the selection, the foci in the bones are removed by a gouge or chisel, and as much of the articular cartilage is saved as is possible. If two-thirds of the articular surface is intact, an attempt to obtain a movable joint (eighteen per cent. in seventy cases, Maudry), should be made, and after dissecting away the posterior synovial membrane and the bursæ, the capsule, the ligamentum patellæ, and the skin should be carefully sutured. The joint is subsequently treated as in fractured patella, with absolute rest from four to six weeks. If one-half to two-thirds is removed by the gouge or chisel, the remaining articular cartilage is removed by sawing intraepiphyseally and an attempt to obtain an immediate bony union in the extended position is made. The atypical and the typical intraepiphyseal operations should be combined in this manner to obtain the best possible result of each method. Kocher, in order to avoid the cutting of the quadriceps tendon, makes the usual curved anterior incision, dividing the skin, subcutaneous tissue, and the fasciæ of the vasti muscles. He then makes upon each side of the quadriceps tendon two vertical incisions, which, meeting the incision in the fasciæ of the vasti, form two right-angled flaps which are retracted outward. The capsule and synovial membrane are now cleared as in the typical excision, and are removed together with the menisci and ligamenta alaria (Kocher). The crucial ligaments having been previously separated at the tibial eminence, the femur is dislocated outward or inward in order that the posterior and posterolateral portions of the capsule be rendered accessible for removal. The condyles are now examined, and, if necessary, foci are removed. The patella is at last turned completely upon itself and cleared of all tuberculous or diseased tissue.

C. P. Flint[22] has devised an excision of knee-joint by the closed method, the purpose of which is to remove the diseased area of bone and cartilage without opening the mass. He employs a long U-shaped incision with its base well above the knee which exposes a large surface of the soft parts, and a short U-shaped incision through the rectus to expose the subcrural bursa. All muscular attachments to the femur are cut through the lateral incisions. A metal guard is slipped behind the head of the tibia and this bone is cut through to the guard by the saw with the limb extended. The head of the bone is then seized, the leg is flexed and the soft parts are freed behind the joint until a point well above the condyles of the femur is reached. A saw is introduced and the femur is cut through from behind forward and slightly downward so as to clear the cartilages behind and to come out on the margin of the articular edge in front. It is easy to make too wide a section on the femur. The saw is withdrawn before complete section is accomplished, but after the subcrural bursa is raised the saw cut is completed from the front. The entire mass now may be removed and the bones treated as after an ordinary excision by the open method.

Dr. J. B. Murphy's method of arthroplasty for ankylosis of the knee-joint[23] is done through a U-shaped incision which commences five centimeters above and three centimeters to the outer side of the patella, passes downward to about the level of the tibial tubercle, and then crosses to the inner side to a corresponding point. (Fig. 2207, *aa'*.) This incision is deepened to expose the joint capsule. On either side flaps of suitable size and U-shaped are raised, to cover the articular surfaces of the femur. The flap base is downward on the level of the articulating surface of the tibia and the convexity is upward. Each flap consists of the lateral portions of the capsule, fascia, and fat. The patella is next detached and displaced laterally in order to expose the joint. The cause of the ankylosis is now determined and carefully removed. If it is a simple fibrous ankylosis the use of a heavy knife suffices to loosen the joint, but great precautions are taken to preserve intact the intercondyloid ridge of the tibia, to prevent subsequent slipping of the femur from side to side. If the ankylosis is osseous, chisels are used, both straight and curved, and if the ankylosis is at a right angle it may be necessary to remove considerable bone before the limb can be brought to a straight line. Under this circumstance all of the bone is removed from the femur and none from the tibia, and the end of the cut femur is reshaped as far as possible, especially creating a new intercondyloid notch. The posterior portion of the capsule is avoided under all circumstances.

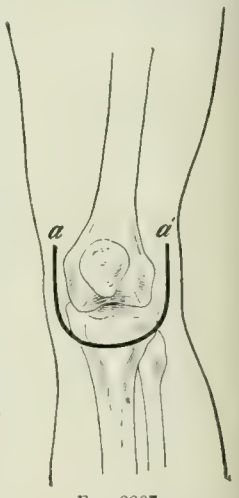

Fig. 2207.

The inner capsule-fascia-fat flap is sutured to the

crucial ligament behind in such a way as to be interposed between the articulating surfaces of the inner condyle of the femur and the inner tuberosity of the tibia. The outer flap is similarly sutured in place over the external condyle and is carried far enough back to overlap the inner flap in the joint. For sutures Murphy uses very fine phosphor-bronze wire, size 12, and finds it flexible and not irritating. In order to prevent the patella uniting to the condyles by fibrous union a flap is taken from the vastus internus and sutured in place beneath it while the remnant of the vastus internus is used to fix the patella in place against outward displacement. If there is much relaxation the patella is completely turned over, thereby giving an additional leverage to the quadriceps, as well as furnishing a smooth surface that will not unite to the femoral condyles.

With respect to the technique of the early stages of this operation, Murphy makes few modifications if any, but he disposes of the patella by several methods, depending on the case. For instance, flaps from the vastus internus and vastus externus may be placed under the patella. Sometimes the patella is split into two parts from above downward, and then the upper half is turned under the lower half, bringing the aponeurotic surface next to the femur. Again, the vastus internus and vastus externus attachments may be freed for a distance of five centimeters above and below the patella, which is dislocated from side to side during the operation. When the interposing flaps are in place the patella is rotated 180 degrees and the vastus internus and externus are sutured to the opposite sides of the patella from which they were freed. Or, finally, a free fascial graft may be taken from the fascia lata and used to cover the condyles of the femur and the under surface of the patella, without rotation of the latter.

In suturing care is taken to avoid tension. The limb is placed in a wire splint or a moulded plaster-of-Paris splint, Buck's extension is used, and the foot raised. Massage and passive exercise are commenced early and a knee support is worn for several months.

Success depends upon the most absolute asepsis, upon the integrity of the circulation, upon the accuracy with which the normal relations are preserved or reconstructed, especially the intercondyloid ridge and notch, and upon a methodical and persistent after-treatment. In some cases, otherwise showing good or fair mobility, there has been lamentable lateral weakness of the knee-joint; in practically all cases there is a rather extraordinary amount of pain after operation; and, finally, it must be borne in mind that this procedure is not entirely devoid of risk to life.

Excision of the Patella.—Primary disease of this bone is not uncommon and may demand excision or resection. Resection is usually done for necrosis and partakes of the nature of a sequestrotomy. Excision involves opening the knee-joint, and therefore all precautions against infection must be taken. As the patella is practically a sesamoid bone developed in the tendon of the quadriceps extensor muscle, it is simply shelled out of that structure through a longitudinal incision. The knife passes directly to the bone and by means of the sharp rugine and periosteal elevator, the quadriceps aponeurosis and periosteum are separated, and then the patella is loosened from the anterior wall of the capsule and removed. The cut edges of the capsule are sutured longitudinally by chromicised catgut, the split quadriceps similarly sutured, the wound closed, and the limb dressed in extension. Recovery should be prompt and the extensor apparatus should be little, if at all, impaired.

Excision of the Femur.—In dealing with the femur it must be remembered that it is the most importan of the long bones of the body because it is concernet with the functions of weight-bearing in the standing posture and with locomotion. Being a single bone, it has not the advantage of a [illegible] when injured or diseased, as both the [illegible] have, so that because of its own size, [illegible] size, weight, and importance of the [illegible], and because of its proximity to the [illegible], a greater degree of shock, operations upon the femur must be undertaken with a greater [illegible] than those upon the other long bones. The teaching up to twenty years ago was that, except in cases of osteomyelitis where limited sequestrotomy sufficed, amputation of the lower extremity [illegible] performed. It is hard to realize how many limbs have been saved by modern methods in bone work and by advances in bone pathology, as instanced by the tendency to ablate or resect instead of amputate in sarcoma of the femur. While in a small series of cases excision (total removal) of the femur subperiosteally performed, and especially in the young, has been followed by reformation of bone with complete or incomplete restoration of function, yet it is by resection (partial removal) that most limbs have been saved, particularly by the use of bone transplants.

The incision for *excision* begins above at the base of the great trochanter, enters the groove between the biceps behind and the vastus externus before, and follows it to terminate at the external condyle below. (Fig. 2203, *a*, *b*.) The bone is reached by passing through this intermuscular plane, and is dealt with as in excision of any other long bone. Fixation and extension are most important after operation.

The incision for *resection* is made along part of the course of that for excision.

Excision of the Hip-joint.—This operation was first performed by Whyte for deformity in 1818, for disease by Hewson in 1822 or by Brodie in 1836, and for gunshot injury by Oppenheim in 1829. The excisions are classed as complete when the acetabulum is partially removed together with the femur; as partial when only the femur or the acetabulum is removed. They are typical or atypical, according to the modifications in the method of approach and the manner of attacking osseous tissue.

The indications for the operation are:

1. Gunshot wounds, where partial and atypical excisions rather than typical and complete methods are undoubtedly indicated. With the new projectiles, conservative methods rather than operative should be employed unless the operative interference is confined to a correction tending to production of better wound healing.

2. Tuberculosis, where operative procedure is not to be delayed, and more conservative measures fail.

3. Deformities from injury or disease. Here partial or complete excisions are alone indicated when osteotomy cannot correct.

4. Old dislocations from disease or traumatism, where partial operations are quite sufficient.

5. Intracapsular fracture of the neck of the femur followed by disability and pain. Here the partial excision confined to the femur is beneficial. To drive a nail through the trochanter into the femoral head generally accomplishes the same purpose.

6. In dislocation of the head and fracture of the neck of the femur. Here removal of the dislocated head is sufficient.

7. Congenital dislocations in adults which have failed of reduction by manipulation. (Lorenz and Hoffa.)

8. In acute infectious arthritis. Here arthrotomy rather than excision will be found to be more beneficial. In modern practice extension with aspiration, and injection of two per cent. solution of formalin in glycerin, after the method of Murphy, is recommended.

Results.—The mortality of excisions for [illegible]

wounds is, according to Culbertson, 89.07 per cent., while according to Gurlt it is 88.23 per cent. Gurlt classifies this mortality as follows: 92.68 per cent. for primary excisions; 94 per cent. for intermediary excisions; 89.39 per cent. for secondary excisions; 60 per cent. for late excisions. Otis gives a mortality of 90.9 per cent. in the primary excisions, while similar cases treated conservatively give 98.8 per cent., and by exarticulation 83.3 per cent.

The mortality for disease is low. Culbertson gives 44.8 per cent., of which 6.93 per cent. represented deaths from operation directly, leaving 37.89 per cent. for deaths from the disease and its complications. Grosch gives a mortality, in 120 cases of tuberculosis treated aseptically and observed to the end, of 36.7 per cent., which, compared with the results of Culbertson in pre-antiseptic times, shows that the cases dying from operation have been excluded by the present methods of operation, but that the deaths from the disease have not been diminished. Nor can it be said that the time of after-treatment is shortened, nor is the functional result better. These statistics include only cases operated upon late in the disease. The results of the operative treatment are better in proportion as the operation is early performed, and better in children than in adults. The mortality in the first stage, *i.e.* in the stage in which the changes in the joint are slight and in which sinuses have not formed, is nil. The mortality in the second stage, *i.e.* in the stage in which fistulæ have formed and pus is present, is 24.1 per cent. The mortality in the third stage, *i.e.* in the stage in which the patients are already debilitated by long-standing suppuration and fistulæ, is 67.5 per cent. Two-thirds of the deaths following operation are due to general tuberculosis or tuberculosis of other organs; one-third is due to septic infection, suppuration, and amyloid degeneration (Bruns). The mortality at present is in the neighborhood of five per cent. (Wright, 3 : 100).

Functional Results.—Baehr reports 44 case sof excision which were able to walk: 8 with perfect motion, 18 per cent.; 23 with restricted motion, 52 per cent.; 11 with ankylosis, 25 per cent.; 1 with a flail joint, 2.5 per cent. Baehr also found that excision of the head alone gave 0.9 centimeters shortening; of the head and neck, 1.5 centimeters. Subtrochanteric section gave a shortening of 4 centimeters. His views substantiate Riedel's, namely, that the early excisions give less shortening than the continuance of the disease will give, and that motion in the joint is equally good or better. Mauninger gives the statistics of 41 cases carefully observed. The shortest time during which a patient was kept under observation after operation was one year and six months. The following are the classified results: 41.02 per cent. were healed without fistulæ; 17.07 per cent. were healed after treatment for fistulæ or after subsequent operations; 9.75 per cent. were healed, but now and then a fistula would open and close. The general health of these patients was good. In 67.84 per cent. the results were good. In 11.19 per cent. of the cases the health was bad, and the wounds suppurated profusely; 21.95 per cent of the patients died. The results were bad in 33.14 per cent. of the cases. Of the deaths (21.95 per cent.), 1 was due to fat emboli in the lungs. In about 10 per cent. the cause was miliary tuberculosis, which followed the operation in from one to five months, and the development of which was probably hastened by the operation. In another 10 per cent. of the cases death was due to tuberculosis of internal organs, the disease developing from one to ten years after the operation.

Functional results in these cases must be considered with reference to the condition of the extremity at the time of operation. In no case had the disease in the hip lasted less than two and three-fourths years, so that the operation had to deal with (1) the shortening of the extremity due to an atrophy from inaction—4 to 8 centimeters; (2) slipping upward of the head of the femur upon the ilium—2 to 3 centimeters; (3) contracture of the soft parts (muscles, etc.), usually a flexion-contracture of thirty degrees and an adduction-contracture of twenty degrees; (4) atrophy of the musculature of the pelvis and femur. Yet, in spite of this condition of affairs, in 50 per cent. of the cases in which good results were obtained good motion was present; in 50 per cent. of these cases a cane with or without a high shoe was used in walking. With the exception of one case, all limped more or less; *i.e.* most patients walked from two to four hours without pain or special fatigue. All followed their vocations. In 50 per cent. their general health was good; in 50 per cent. it was very good. With the exception of one case in which multiple caries existed, no case was suspected of having tuberculosis in other organs. Mauninger collected, in addition to these cases, 304 cases which were operated in the aseptic period of surgery. Permanent healing took place in 65.8 per cent. The mortality was 17.4 per cent. The question to-day is whether conservative treatment will give as good or better results than the operation.

The statistics of Gibney, Waterman, and Reynolds,[24] of 114 cases examined five years and upward after leaving the hospital, show that 107 were cured and able to follow an occupation without trouble; 7 cases were cured, but with considerable deformity, for which osteotomy or excision was done. About 14 per cent. showed perfect motion, 20.5 per cent. good motion, 38 per cent. limited motion, and no motion in about 8 per cent. Shortening of the limb averaged 1.75 in. (4 centimeters) in all the cases except in 21 in which it was absent, *i.e.* 19.5 per cent.

The statistics of Mauninger, obtained for the conservatively treated cases, give the following results as regards the cures and deaths: purulent cases, 27.1 per cent. healed, 48.8 per cent. mortality; non-purulent cases, 74.2 per cent. healed, 16.5 per cent. mortality.

The results of conservative treatment are, therefore, with reference to mortality, no better than those obtained by the operative method, for even if the cases of death due to operation alone or induced by the operation be included, still the operative cures present a mortality of only 17.4 per cent. as against 16.5 per cent. in the non-suppurative cases and 48.8 per cent. in the suppurative cases treated conservatively. If in this comparison cases be deducted in which the disease is attacked early before suppuration exists, the mortality ranges from 0 (Bruns) to 3 per cent. (Wright)—a result far superior to that shown by the statistics of the cases treated conservatively, and even better than the results obtained by Gibney (8.8 per cent.) or by Marsh (6 to 8 per cent.) for the conservative treatment.

The functional results are quite as good—perfect motion being obtained in 18 per cent. of the operative cases (Baehr), in 14 per cent. of the conservative (Gibney, *et al.*). Even in the cases reported by Mauninger, operated after two and three-fourths years of the disease, 67 per cent. were good results; one-half of these patients had motion and one-half walked with a cane. All could follow their vocations. These excellent results obtained by both methods of treatment depend much upon two factors. In the first place, in the conservatively treated, some cases of *restitutio ad integrum* are due to the fact that the disease was non-tuberculous (Karewski). Again, in the cases treated by operation much will depend upon the time at which the operation is performed. Operations are not to be performed because conservative treatment has failed, but at an early stage when fistulæ and suppuration are not present, or, if they are present, only to a small extent.

The shortening in the limb is less by the operative treatment than by the conservative treatment. In

the older cases the average shortening from operative procedures is not increased over that which is present at the time of operation and which is due to the atrophy of inaction, the slipping upward of the head of the femur, and the contracture of the limb. In the early cases, the statistics of Baehr show that shortening for any section made on a line situated higher up than below the trochanter is very slight (0.9 to 1.5 centimeters), while average shortening in the conservative treatment is 4 centimeters, with 19 per cent. of the cases showing practically no shortening (Gibney), *i.e.* less than one-half inch or 1.25 centimeters. Operation should be carried out as soon as it is clear that conservative measures cannot prevent suppuration. An excision is indicated so soon as suppuration exists in the joint and before fistulæ are present (König).

In the wealthy class, where long-continued mechanical treatment can be carried out and where iodoform injections can be made as indicated, suppuration can oftentimes be prevented and a result obtained which, as we have seen, gives perfect motion in fourteen per cent. of the cases. In the poorer class, who cannot afford or will not carry out this long-continued mechanical treatment, suppuration is more frequent, the deformity is greater, and the destruction of the bones is more marked than is the case in those who have been able to command mechanical treatment and have followed it faithfully. In these latter cases operative treatment is frequently indicated and will give results superior to those offered by the conservative treatment, both in respect to function and in respect to mortality, when like degrees of disease are compared.

Anatomy.—The hip-joint is deeply placed and is immediately surrounded by the psoas and iliacus muscles before; by the quadratus femoris, the obturator internus, the gemelli, and the pyriformis behind; by the gluteus medius, gluteus minimus, and rectus femoris externally; and finally by the pectineus and obturator externus internally. Beneath these muscles is the thick capsule, the auxiliary bands of which are the iliofemoral, the pectineofemoral, and the ischiofemoral, the border of which latter is known as the zona orbicularis. Between the ilio- and ischiofemoral bands the capsule is strong; opposite the lower and back part of the femoral neck and opposite the cotyloid notch it is thin. Within the joint is the ligamentum teres, a round band extending from the acetabular notch to the depression in the head of the femur. The cotyloid fibrocartilage and the transverse ligament complete the ligamentous structures. The synovial membrane lines the capsule and passes over the border of the acetabulum to cover the round ligament. The bursæ are numerous and of frequent occurrence; upon the outer and anterior surfaces there are five, while upon the posterior surface there are four.

The bones consist of the innominate and the femur. The former contains the acetabulum, a hemispherical cavity which receives the femur. The latter presents a rounded head and a neck, which is long and joins the shaft obliquely, *i.e.* at an angle of 125 degrees. Ossification occurs in the head of the femur and in the greater and lesser trochanters, respectively, at the first, fourth, and thirteenth years. They join the shaft in the reverse order at the eighteenth, eighteenth and a half, and nineteenth years. The acetabulum ossifies at the sixth year from the Y-shaped cartilage occupying its center. At the fourteenth the ilium and ischium unite with the acetabulum. The pubis does so at the fifteenth year. Ossification is completed in the acetabulum at the seventeenth year.

Owing to the obliquity and the length of the neck of the femur, the muscular attachments to the bony prominences have great leverage, and a wide range of motion is possible. When the head is removed these muscles tend to draw the femur upward unless the neck is engaged in the acetabular cavity. If the neck is also removed, abduction and [illegible] of the femur are lost. Contracture of [illegible] sing between the pelvis and the femur to ascend, which occurs [illegible] the tension of the capsule. The [illegible] in any excision will depend upon: (1) [illegible] epiphyseal cartilage. This is slight. (2) The amount of bone removed. (3) The muscular displacement of the femur. (4) The atrophy of [illegible] disuse. This shortening is partly [illegible] inclination of the pelvis on the side operated. The object to be acquired in an excision is a nearthrosis

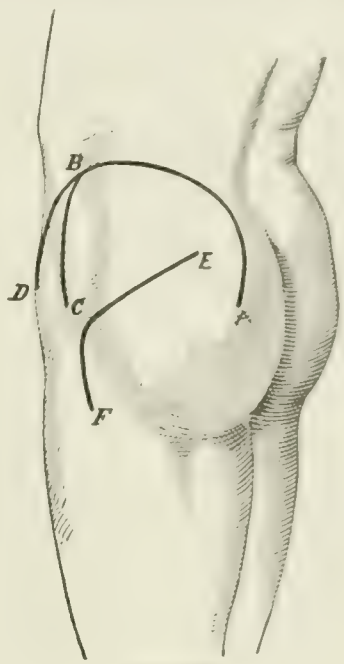

Fig. 2208

or a tight pseudarthrosis. They give the best results in walking. To obtain either, the neck must be retained in the acetabulum or in apposition with the bone at this level, and not allowed to ascend. Owing to the inclination of the pelvis after shortening, the femur must be retained slightly flexed and abducted upon the pelvis. The main points, then, are to preserve the greatest possible length, to obtain a stable, slightly mobile union with the acetabulum, and, lastly, to preserve the proper position in the limb.

Methods.—The hip-joint has been removed by several methods of incision. 1. By the external incision. First proposed by Charles White in 1769, and modified by Langenbeck in 1867, by Sayre in 1874, and still later by Ollier and Kocher. 2. By the anterior incisions. (*a*) The longitudinal; (*b*) the transverse. 3. Posterior incisions, Hueter; Guérin, Bidder. 4. Superior incisions, Bardenheuer, H. Schmid, Sprengel.

In addition to these, there are from fifteen to eighteen other modifications of these methods of approaching the joint (Farabœuf[25]). They are of little value. Of these methods of entering the joint three are selected: 1. The external incision. 2. The anterior longitudinal incision. 3. The superior incision.

1. *Operation by the External* [illegible] The patient lies upon his sound side with the thigh flexed upon the pelvis at an angle of forty-five degrees. It is also rotated inward. One assistant holds the limb with one hand upon the knee and the other upon the foot and produces the required positions during the opera-

tion. The operator stands behind the thigh and is usually aided by two assistants.

An incision is made which may correspond to that of Langenbeck, Sayre, Ollier, or Kocher. If Langenbeck's is selected, it passes from the posterior superior iliac spine over the great trochanter behind its center and follows the axis of the femur. Two-thirds of this incision is above the trochanter, one-third is below it. If Sayre's incision is selected, it passes from a point midway between the anterior inferior spine and the trochanter across the top of the great trochanter behind the center, and curves thence forward and inward. If Ollier's incision is selected, we flex the thigh on the pelvis at 125 degrees. From a point four fingers' breadth behind the anterior superior spine and the same distance below the crest of the ilium, the incision passes downward and forward in the direction of the fibers of the gluteus medius to the trochanter, thence forward and downward in the axis of the femur. If Kocher's incision is selected, it commences at a point opposite the upper border of the great sciatic notch in a line connecting the posterior superior spine of the ilium and the center of the trochanter major, and descends parallel to the fibers of the gluteus maximus to the trochanter major on its external surface. From this point it bends backward and downward. The upper limb of this curve is usually eight centimeters in length, the lower six to eight centimeters. (Fig. 2208, *EF*.)

Of these incisions Kocher's[26] is to be preferred, because of the ready exposure of the parts which it affords, and the easy access which it gives to the joint through the muscular interstices, thereby avoiding the arterial and nerve supply of the muscles.

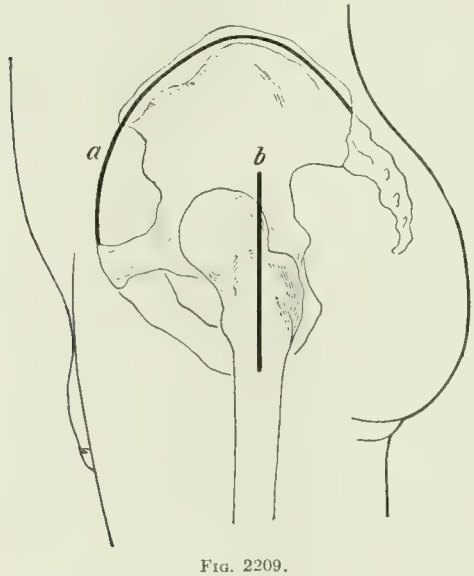

Fig. 2209.

Having selected the latter incision, the surgeon should divide the skin and deep fascia and thus expose the fibers of the gluteus maximus in the upper two-thirds of the cut. These are divided parallel to their length and in the line of the skin incision. Two or three branches of the gluteal artery are usually cut here in their middle. Two retractors are introduced, the gluteus medius and pyriformis are exposed beneath this muscle internally, while externally the trochanter is felt. The knife now divides the strong fascial attachment of the gluteus maximus, passing over the trochanter and descending in the interstice between the vastus externus and the quadratus femoris. In this incision the tendon of the gluteus maximus is in part divided, and this division, by reason of the resulting retraction, exposes the muscles covering the joint behind and the trochanter in front. It is here that the external circumflex artery is sometimes cut. The interstice between the pyriformis behind and below, and the gluteus medius above and in front, is seen in the anterior part of the exposed area. Below this is seen the interstice between the pyriformis above and the gemelli and obturator internus below. It is between the latter muscles that the incision is deepened, since in the upper retracted flap will be the gluteus medius and pyriformis supplied by the superior gluteal nerve, while in the lower retracted flap will

Fig. 2210.

be the obturator internus and gemelli supplied by the inferior gluteal artery. The joint capsule is now exposed throughout its length and should be divided by an incision which runs parallel to the axis of the neck of the femur, and at the same time divides the periosteum of the neck, the orbicular zone of the ischiofemoral band, the capsule and the circumferential fibrocartilage of the acetabulum. This incision is usually sufficient to allow dislocation of the head of the femur, but, if it does not suffice, a transverse incision may be added near the acetabular margin. The internal circumflex artery is usually cut here as it passes over the capsule. The incision in the periosteum of the neck is now continued over the trochanter major upon its posterior border, and the periosteum, together with the attachment of the gluteus medius above, the pyriformis internally, the gluteus minimus, the vastus externus, and the Y-ligament anteriorly, is separated with the rugine. This separation is greatly facilitated by flexion and rotation outward of the thigh. It is here that the external circumflex artery is often cut a second time. This flap can now be pulled forward over the trochanter. It contains within, if we exclude the small portion of the vastus externus, only those muscles which are supplied by the superior gluteal nerve. The thigh is now less flexed, adducted, and rotated inward. The tendons and the periosteum are separated with the rugine from the apex and posterior half of the trochanter as far as the origin of the quadratus femoris from the linea quadrati. These tendons, namely, the gemelli, the obturator internus and externus, and as much as is necessary of the quadratus femoris, are now retracted backward and downward with the capsule. The nerves to these muscles are thus uninjured.

When these capsulo-periosteal flaps are freely retracted the posterior surface of the head of the femur, its neck, and the trochanter are in view. The sciatic nerve is free from danger, being carried away from the joint when the obturator internus, the obturator externus, and the quadratus femoris are divided and retracted.

The thigh is now strongly flexed, adducted, and rotated inward. The round ligament is divided if intact and the head is luxated. The remaining periosteum and capsule upon the neck are separated with the rugine. The head is now held firmly with the lion-jawed forceps, the soft parts are protected by the retractors, and the bone is sawn with the Gigli saw just below the level of disease or injury.

The acetabulum is next removed with the gouge, chisel, or Volkmann's spoon, according to the indications. The synovial membrane and parts of the capsule are removed after the bones are cleared of disease. If sinuses are present they must be excised or curetted. Hemorrhage usually consists of oozing, and can be stopped by hot saline solution; if it is very troublesome, the wound may be packed with gauze. Where no oozing is present and no sinuses exist the wound may be closed directly. If, however, abscesses, sinuses, or great oozing is present, it is best to drain with rubber or pack with gauze, for a time at least.

The section in the bone should be made in the neck if possible; if not, through or beneath the trochanter major, because of the shortening which is liable to ensue. (Fig. 2212, *a*, *b*.)

A nearthrosis is best secured when the section passes through the neck near the head, yet subtrochanteric sections have given as good results in the restoration of the joint. Such cases are seen in the autopsy

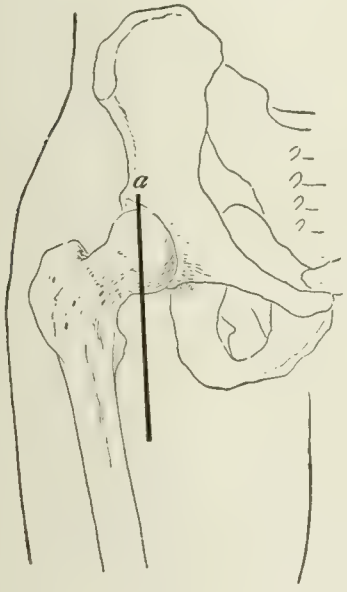

Fig. 2211.

shown by J. Israel and in the collection made by Sach. In some of these cases a newly formed head covered with fibrocartilage, a new trochanter, and synovial membrane were reproduced to a considerable extent. To obtain the best results, one must operate early in the disease, early in life (three to fifteeen years), and subperiosteally, and must preserve as much of the bones as possible, so as to diminish the shortening. When a nearthrosis is not attainable or is inadvisable, the after-treatment should secure the retention of the limb in abduction with the [illegible]. This gives a very good and [illegible]

2. *Operation by the Anterior Incision.*—[illegible] incisions here considered are those which are longitudinal. The transverse are too destructive of the soft parts.

According to Lücke and Schede, the [illegible] commences one finger's breadth, more or less, to the outer side of the anterior spine and descends in the long axis of the femur for a distance of ten to twelve centimeters (Fig. 2211). As it is deepened it passes to the inner side of the sartorius and the rectus muscles and to the outer side of the iliopsoas muscle. The anterior crural nerve and the external circumflex artery are avoided. The assistant flexes, abducts, and rotates outward the thigh. The sartorius and rectus muscles are drawn outward, the iliopsoas muscle and the crural nerve inward. The capsule of the joint is exposed and is divided by a crossed incision, the transverse portion parallel to the neck passing from the acetabulum over to the anterior intertrochanteric line, while the vertical portion crosses this line at a right angle. The neck is now sawn with a Gigli saw and the head is extracted after dividing the ligamentum teres by Löbker's spoon-elevator or by a lion-jawed forceps. For the extraction of the head alone this incision may suffice, but if we wish to reach the trochanter in addition we must advocate the incision of Hueter which has been much used and strongly advocated by Barker. In this latter method, the patient rests supine with the thighs extended; the surgeon makes an incision which, according to Hueter, passes from the middle of a line drawn from the anterior superior iliac spine to the trochanter major, downward and slightly inward along the outer border of the sartorius. In children the incision is six to eight centimeters; in adults ten to fifteen centimeters in length. According to Barker, the incision commences in the anterior surface of the thigh, one-half inch below the anterior superior spine of the ilium, and runs downward and inward for three inches. With either incision, the dissection is carried on in the space between the sartorius anteriorly, and the tensor fasciæ femoris and the gluteus medius behind. The incision is deepened to the bone and some fibers of the vastus externus are divided. In the lower angle of the wound is seen the external circumflex artery, which may be divided. These muscles are retracted, the joint capsule is seen and is incised by the same cross incision mentioned in the Schede-Lücke method. After this exposure of the head and neck, the spoon-elevator may be used and the trochanter freed of its muscles sufficiently to allow an easy exposure of the joint. The diseased head is now removed after encircling the neck and dividing it with the Gigli saw. The removal of the head is often difficult unless it be much diseased. The easiest method is to pry the head out of the acetabulum by introducing a strong, gently curved elevator or Löbker's spoon in the space between the head and the acetabulum, and after the ligamentum teres has been divided the head is then easily removed. The bleeding by this anterior incision is small in amount if one avoids the anterior circumflex artery. Drainage of the wound will require not infrequently a posterior opening, but in many cases operated early all necessary drainage can be secured through the anterior incision.

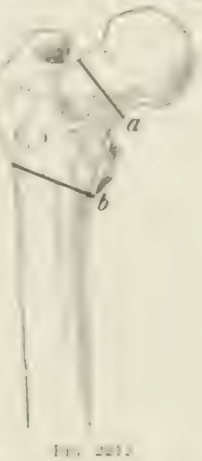

Fig. 2212.

In neither of these methods by the anterior incision

are muscles cut. Neither nerves nor vessels are injured. In both methods the route to the joint is a direct one. The advantage of the Hueter incision over the Lücke-Schede incision is that the trochanter, as well as the head and neck, can be reached.

When the acetabulum is primarily involved, or the *x*-ray and the clinical symptoms show that the disease which affects it must be especially attacked, the methods introduced by Bardenheuer and Schmid give the best chances for radical cure. As usual methods, these procedures are considered at present too extensive. In Bardenheuer's hands, the mortality due to the operation alone was 4.3 per cent. In Schmid's hands, the recurrences were not lessened by the procedure, two of the four cases dying of continued tuberculosis. In the large majority of cases the Kocher incision will give sufficient exposure to enable us to chisel or gouge away the diseased acetabulum; and as this method is less extensive and more easily accomplished it should be preferred.

Operation by the Superior Incision.—In a few cases, Kocher's operation is not sufficient, and we recommend for these the suggestion of Sprengel,[27] which consists in making an extensive incision along the crest of the ilium from the posterior superior spine of the ilium to the anterior superior spine. (Fig. 2208, *ABC*.) This incision divides the muscles and the periosteum. At the border of the gluteus medius and the tensor vaginæ femoris this incision descends to the trochanter major. This quadrilateral flap is removed

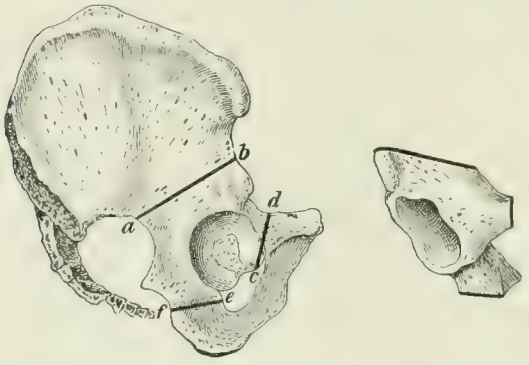

Fig. 2213.

subperiosteally from the ilium until the joint is opened and the head and neck of the femur are exposed. As the nerves and vessels are avoided by this, the muscular paralysis and hemorrhage are practically nil. If the disease is well forward in the acetabulum and pubis, especially if a flexion-contracture exists, the incision is made in front of the tensor vaginæ femoris, sartorius and rectus and these muscles are separated with the rest (Fig. 2208, *ABD*). After exposing the head of the femur, it is rotated inward or outward, as occasion demands and adducted strongly. If the acetabulum alone is to be removed, this can be easily accomplished with the chisel or gouge through the incision first recommended (*ABC*). If the disease requires an excision of the acetabulum and the surrounding bone, the second incision is used (*ABD*). In this latter case the outer surfaces of the ilium, the acetabulum, and the outer margin of the great sciatic notch are bared of their periosteum. In like manner the internal surface of the ilium, the iliac fossa, is freed from the pelvic fascia and muscles until the great sciatic notch is reached. A Gigli saw is then inserted through the sciatic notch beneath the iliac muscles and over the anterior inferior spine of the ilium and the bone is sawn (Figs. 2213 and 2215 *ab*). The horizontal ramus of the pubis is next cleared of its periosteum, carrying with it the vessels, which are displaced from one to two centimeters internally. An aneurysm needle now carries a Gigli saw around the ramus and out of the obturator foramen (Fig. 2215, *cd*). The bone is sawn. As the bone is now cut upon two sides, it can be displaced somewhat outward. The periosteum is next removed from the body of the ischium from above downward with great care to avoid injuring the vessels and nerves as they pass out of the pelvis. The Gigli saw is passed around the body at a point one finger's breadth below the acetabulum (Figs. 2213 and 2215, *ef*). The bone is sawn. The acetabulum and surrounding bone can now be quite easily removed with the heavy lion-jawed forceps. If the head of the femur is to be removed with the acetabulum, it is best removed before we attempt the excision of the acetabulum.

Fig. 2214.—A Patient Three and a Half Years after Removal of One-half the Pelvis and the Head of the Femur. (Kocher.)

After the hemorrhage has been controlled the wound isclosed with sutures, except in some portion where the packing emerges. It is best in all cases to pack the large wounds from twenty-four to forty-eight hours, in order to control hemorrhage completely. After this, that portion from which the gauze emerges can be left for drainage or it may be sutured at this time.

After-treatment.—The after-treatment in excision of the hip is important. An aseptic dressing, equable compression, and rest for the wound are the prime desiderata. The position to be maintained is that of extension and adduction of the thigh, with the neck or the trochanter closely applied to the acetabulum or ilium. During the first three weeks, since these wounds are packed with gauze and require secondary

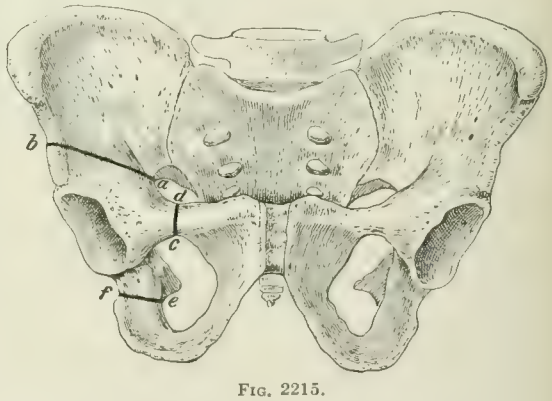

Fig. 2215.

suture or dressings, a Buck's or Volkmann's extension apparatus with plaster-of-Paris spica passing to the knee is most frequently used. After this period,

when the packing is removed or the wound is healed in great part, a Thomas splint or the plaster-of-Paris dressing may be used for the next three weeks. If the patient is up and about upon crutches (children), a Thomas splint is very inexpensive and satisfactory. If the patient is confined to bed, a plaster-of-Paris splint which can be readily removed for the active exercise of the joint is the more useful form of splint. During this period of three weeks, active exercise in the new joint is made every two or three days.

During the following three to six weeks patients are allowed to walk with their splints, and during this time the Taylor hip splint or some modification of it is substituted for the former apparatus. These splints allow flexion, extension, and abduction when applied, and the surgeon must continue the extension and abduction of the limb for a long time to overcome the constant tendency to flexion and adduction. It is only by this careful after-treatment that a good functional result can be obtained.

Ankylosis of the hip-joint in good position usually represents the best results obtainable in many cases, but there is still a large class of patients in whom there is ankylosis in such faulty position that operative measures are demanded. Formerly, the most that could be offered these unfortunates was a resection or excision of the hip-joint, or an osteotomy of the neck of the femur, with correction of the deformity and sometimes an attempt to secure partial mobility by the after-treatment. With the introduction and development of the interposition-flap method of treating ankylosis, a decided advance has been made and the reconstruction of the hip-joint is now recognized as a sound and successful procedure.

Enough has been said elsewhere concerning the general principles involved, and emphasis has been laid upon the importance of experience, sound judgment and thorough knowledge of anatomy and pathology on the part of the operator. The hip-joint is not an unfavorable joint for the application of interposition methods; in fact, it is one of the most favorable in the body and the results obtained by Murphy and others have been highly gratifying in the main.

No attempt will be made to describe in accurate detail the operation since in this joint, as elsewhere, a wide latitude is not only permissible but incumbent upon the surgeon. As a rule the posterior incision of Kocher provides the best access to the involved area and is less liable to endanger important structures. By cutting through the aponeurotic insertion of the gluteus maximus on the outer aspect of the trochanter, the interval is reached between the lower border of the gluteus medius and minimus above and the pyriformis below. From this point the periosteum is incised along the anterior intertrochanteric line and detached forward, carrying with it the insertions of the gluteus medius and minimus and the iliofemoral ligament. The insertion of the pyriformis is similarly raised, and then the external rotators are retracted backward with the periosteum. The capsule is opened along the upper border of the tendon of the pyriformis. In ankylosis these structures are rudimentary, but it must be remembered that with restored mobility each tendon and muscle will be expected to do its part in restoring function and that observance of the posterior method of approach where possible, together with strict subperiosteal detachment of muscles and tendons, will be conserving factors of great importance. Long before the actual ankylosed joint is reached pathological changes will be in evidence, but the exact cause of the ankylosis must be determined at the joint. If it is due to fibrous adhesions they may be entirely severed without greatly disturbing the joint relations. On the other hand, if it is due to osseous ankylosis the curved and straight chisels are required, first, to separate the head of the femur from the acetabulum, and then to reshape the component structures, or in other words to construct a ball-and-socket joint. It may be necessary to remove a part or all of the femoral head or to gouge out a new acetabulum. Whatever is done it is obligatory not only to restore the relations but also the shape as far as possible. When this is done the next step is to insert an interposing structure which will help to form a new joint or to create a relatively [illegible] ankylosis which will permit of motion. For this purpose a flap of the fascia lata is [illegible] turned up to act as an interposing membrane or an entirely detached portion of the fascia lata may be used; or a part of the aponeurotic insertion of the gluteus maximus and some of that muscle [illegible] or, finally, Baer's animal membrane (chromicized pig's bladder) may be employed. Whatever structure is selected it must be rather loosely placed around the femoral head, avoiding tension, and sutured in place to the margins of the capsule. With the exception of the external circumflex artery there should be no bleeding point requiring a ligature. The capsule is closed if there is enough left, the periosteum and the attached muscles restored to the normal position and the wound closed with a twenty-four hour drain. The limb and pelvis are fixed in a plaster-of-Paris case with the limb in abduction and the femoral head in contact with the acetabulum. Gentle massage and passive exercise may be commenced in ten days or two weeks.

Excision of the Innominate Bone. Resections of the pelvis are not infrequently performed, but excision of the innominate bone is a rare operation. It was first done by Dr. Theodor Kocher in 1884 for osteochondrosarcoma of the pelvis in a man of fifty-one years. The pubis and ischium were divided two centimeters internal to the acetabulum, and the ilium separated posteriorly at the sacro-iliac synchondrosis. About twenty-five years later a similar operation was performed by Kocher on a boy, aged thirteen, for sarcoma of the pelvis.

The incision begins at the sacroiliac joint, passes along the iliac crest, and thence along Poupart's ligament. (2209, *AC.*) The abdominal muscles are divided from their attachments along this incision, and the transversalis fascia and peritoneum are separated as far as the iliac vessels and retracted still further inward. The muscles beneath Poupart's ligament and external to the iliac vessels are divided. The rectus femoris, sartorius, tensor fasciæ femoris, and the attachments of the gluteus medius and minimus to the ilium are detached and divided as far back as the sacroiliac joint. The iliopsoas and the capsule of the joint are then divided and the pubis and ischium are cut by a Gigli saw or strong forceps. The sacroiliac joint is now split from above downward and the [illegible] dislocated downward. The posterior aspect of the pelvis is exposed and the flexor muscles detached. Finally, the greater and lesser sacrosciatic ligaments are cut and the bone is free. Hemorrhage is not excessive but Kocher recommends that the internal iliac vessels be tied when exposed. Both of Kocher's patients recovered. (Fig. 2214.)

Excision of the Temporomaxillary Joint. Inflammations of this joint are comparatively rare and are usually metastatic in origin. When they occur, however, almost invariably ankylosis results and, as ankylosis at this point is highly disabling, operation is required. If articular ankylosis occurs in childhood, as frequently happens, the loss of function in the jaw retards its development and results in a receding chin which gives a "bird-like" profile. Habitual and unreduced dislocations of the mandible are also indications for excision. A true ankylosis of one side is sufficient to limit entirely the motion of the jaw, and a reference to the history is necessary to determine whether unilateral or bilateral excision is necessary.

In former times surgeons resorted to osteotomy, sometimes of the ramus of the jaw, sometimes of the neck of the condyle, sometimes of the coronoid process, and sometimes of combinations of these, but modern surgery tends toward excision of the condyle with the introduction of measures to ensure mobility. The chief danger in the operation as done to-day lies in injury to the facial nerve, especially the malar branches. The auriculotemporal nerve lies behind the condyle and the internal maxillary artery crosses below the neck. Steno's duct is two centimeters below the zygoma. The introduction of an interposition flap to prevent recurrent ankylosis dates from 1860 when Verneuil[28] placed a flap of temporal muscle and fascia between the condyle and the glenoid cavity. In 1893 Helferich similarly treated a one-year-old child after resecting the malar bone. Mikulicz and Rochet employed the masseter for the same purpose and avoided malar resection. Brackett[29] has successfully employed Baer's chromicized pig's bladder (forty days) at the temporomaxillary articulation.

Among the many operations which have been devised for excision of this joint none seems to possess greater merit or wider applicability than that first suggested by Dr. Howard Lilienthal,[30] of New York. An angled incision is made, the horizontal portion extending five centimeters along the zygoma, and the vertical portion running downward four centimeters in front of the ear toward the angle of the jaw. The horizontal incision goes down to the periosteum but the vertical incision only passes through the skin. The triangular flap thus formed is dissected loose and retracted forward. (Fig. 2216.) A strong, curved, rather blunt needle is passed beneath the posterior part of the zygoma and emerges above it. This needle is threaded with coarse silk which serves to draw through a fine

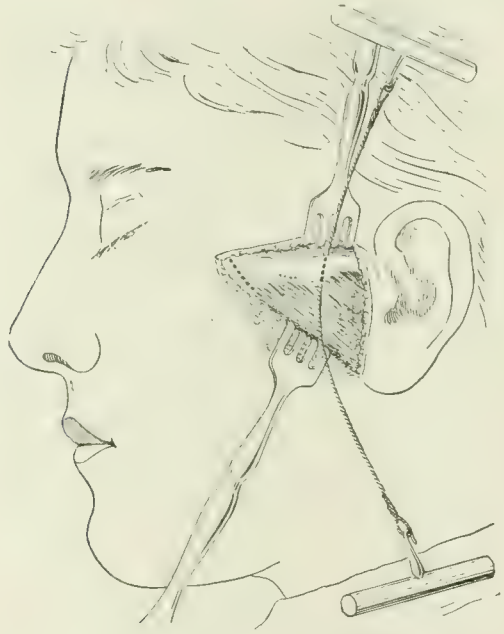

Fig. 2216.—(After Lilienthal.)

Gigli saw and the zygoma with its periosteum intact is cut through with the section running upward and backward. (Fig. 2216.) In a similar manner the Gigli saw is drawn under the anterior portion of the zygoma and a section is made running upward and forward. The severed section of the zygoma is now turned downward, carrying with it the attached masseter muscle, part of the parotid gland, and the facial nerve. The area of the articulation is now perfectly exposed, the cause of the ankylosis may be clearly demonstrated and removed. Excision of the condyle may be done by bone forceps, or better, the chisel (Putti).

The section of the zygoma when replaced is apt to remain in position, but Lilienthal suggested that it be sutured by one or two fine chromic catgut sutures in case of doubt. The simplicity and safety of this operation strongly commend it and the resultant scar should be scarcely noticeable. There is an

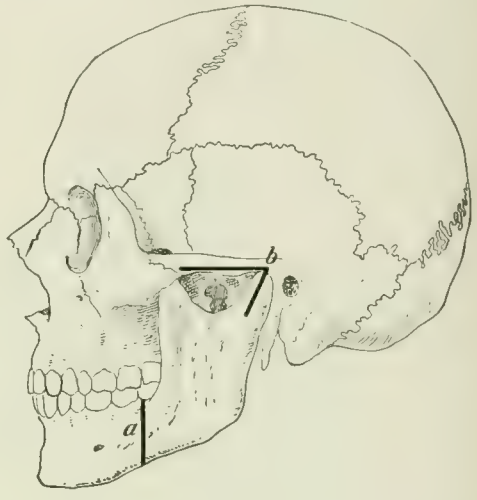

Fig. 2217.

appreciable risk of infection on account of the proximity to the hair line, but this may be avoided by scrupulous asepsis. J. H. Jopson has refined Lilienthal's operation practically by insuring subsequent free mobility through the use of an interposing flap taken from the temporal fascia. The after-treatment consists chiefly of systematic exercise in season and out of season; but in this excision the maximum degree of improvement is more quickly reached and sustained than at any other joint, usually in eight or ten weeks.

If, for any reason the section of the zygoma is deemed inadvisable, the condyle may be removed through an angular incision after the method of Abbe. (Fig. 2217, *b*.) This consists of a horizontal incision along the lower border of the zygoma for the distance of four centimeters, and a vertical cut downward and in front of the temporal artery to a point just above the transverse facial artery (two centimeters below the zygoma). The triangular flap is turned downward and forward and if the lower angle of the wound is retracted downward, Steno's duct, the facial nerve, and the transverse facial artery are kept secure. It is also necessary to draw backward the vertical wound to avoid the anterior margin of the parotid gland. A few fibers of the masseter muscle should be divided from the zygoma when the capsule of the joint appears. This is divided vertically and the neck of the condyle is cleared by closely hugging it. With bone-cutting forceps, or a chisel, or the Gigli saw, the neck is severed as close to the condyle as possible. The latter is then removed with minimum damage to the capsule. The capsule is sutured with fine chromic catgut, the divided masseter fibers stitched to the zygomatic periosteum, and the wound closed with temporary drainage.

As a rule, with this operation the glenoid cavity and the interarticular cartilage are left undisturbed. If interposing structures are used to reconstruct a joint, the masseter muscle and Baer's membrane are available, but with the Lilienthal method or some variation of it, such as that of Murphy, where the

zygoma is removed, the temporal fascia can be used. The consensus of surgical opinion seems strongly to prefer the latter.

In the majority of cases unilateral excision will not suffice to render the jaw freely movable, and, under these circumstances, bilateral excision should be done at the same séance. Infrequently osteotomy of one or both coronoid processes is needed to supplement bilateral excision.

Excision of the Superior Maxilla.—Partial removal of the superior maxilla for alveolar growths, necrosis, disease of the antrum of Highmore, etc., has probably been practised for a very long time, but the complete, formal excision of this bone appears to have been first proposed by Lizars in 1826. In the following year Gensoul, quite independently of Lizars' suggestion, performed the operation, and therefore seems entitled to the credit of having first executed this procedure.

The indication for excision of the upper jaw is almost invariably the presence of a new growth. Hueter states that the jaws are more frequently the seat of tumors than any other bones of the skeleton. Almost every variety of neoplasm is found in connection with these bones. Benign tumors such as cysts, epulis, adenomas, fibromas, chondromas, osteomas, etc., require partial excision only, merely enough of the bone being removed to give access to the tumor or to effect the complete removal of the latter. Complete excision of the superior maxilla is

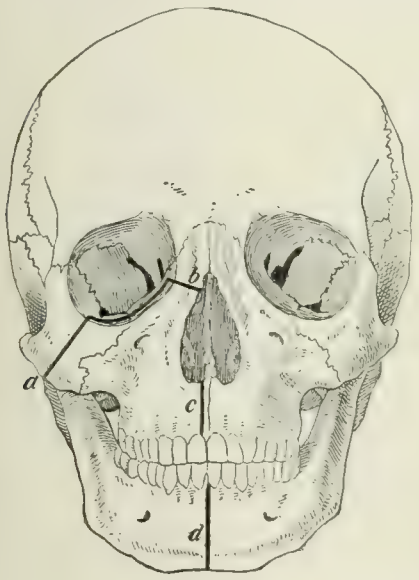

Fig. 2218.

usually done for malignant growths, *i.e.* carcinomas and sarcomas, affecting the bone. They occur with about equal frequency. The majority of the former begin in the alveolus.

Anatomy.—The superior maxilla is the largest bone of the face, the lower jaw (mandible) excepted, and with its fellow forms the whole of the upper jaw. Each bone forms a part of the wall of three cavities: the mouth, the nasal fossæ, and the orbit. It is hollow, its cavity being known as the antrum of Highmore, which communicates by an aperture with the middle meatus of the nasal fossa. Any of these cavities may be the seat of new growths which involve the maxilla, the mouth and the antrum being most frequently affected. The mucous membrane of the antrum is frequently the seat of a catarrhal or purulent inflammation, giving rise to an excessive discharge through the nose, or if the [illegible] escaping, the thin walls of the [illegible] toward the cheek, tow[illegible] tions, the appearance [illegible] in solid growths of the bone.

Instruments Required.—Mouth gag, [illegible] scalpels, toothed dissecting forceps, hemostatic forceps, scissors, keyhole saw, Hey's saw, tooth forceps, bone-cutting forceps of [illegible] chisels and mallet, lion-jaw forceps, sequestrum forceps, Paquelin or electric cautery, tracheotomy tube, needles, straight and curved, ligatures, sutures, gauze sponges.

Resection for alveolar tumors and necrosis may be performed through the mouth in most instances, without making any external incisions. The removal of other benign growths must be carried out on general surgical principles. The affected part is approached by incisions designed to avoid important structures and to give the best exposure with the minimum resulting deformity, and the neoplasm, together with the bone to which it is attached, is then removed. If the tumor is open to the suspicion of being malignant, a generous portion of the adjacent bone in all directions should be removed, or the complete excision may be advisable.

The dangers of excision of the superior maxilla are hemorrhage, the entrance of blood into the air passages, and septic pneumonia. Various means have been adopted by different operators with the view of controlling the hemorrhage. The internal maxillary and temporal arteries, and the external carotid artery have been ligated as a preliminary step in the excision. The common carotid has been compressed and subjected to temporary and permanent ligation. Crile has devised a clamp to be applied to one or both common carotids, as may be necessary, for the temporary control of bleeding during operations on the head and face if serious hemorrhage is probable. As the indications for complete excision are usually found with malignancy, a preliminary dissection of cervical lymph nodes is usually demanded, and when that is done a temporary ligature or clamp may be put on the external carotid artery.

With the view of preventing the blood from flowing into the air passages, Rose advises that the patient's head be allowed to project beyond the end of the table, and to drop well down so that the vertex points vertically to the floor. In this position the mouth and nose are on a lower level than the larynx and the blood would escape from them before it would enter the latter. The objection to this position is that the surgeon is obliged to work at a great disadvantage, and the hemorrhage is greater when the head is dependent than when it is elevated.

Some surgeons have performed a preliminary tracheotomy, introducing a tube and continuing the anesthesia through this, so that the pharynx could be packed with gauze sponges to which stout strings had been attached to assist in their withdrawal. Of this procedure it may be said that while a carefully performed tracheotomy that is well cared for afterward does not add much to the dangers of the operation, it is an additional complication, and is usually unnecessary.

Since the introduction of the intratracheal method of anesthesia practically all difficulties in the prevention of blood entering the air passages have disappeared. Ether anesthesia is started in the ordinary way and, when the patient is [illegible] tube is introduced by the Chevalier Jackson speculum and the mixture of ether and air, or ether and oxygen, is turned on. The pressure of this current may easily be regulated to absolutely preclude any blood or oral discharge getting into the lungs, and at the same time an easy, smooth anesthesia is insured.

To summarize, it may be [illegible] position is not to be recommended. (2) The intra-

tracheal, positive pressure method of anesthesia is ideal in keeping the air passages free of blood and discharges. If this is not available it is advisable to give a preliminary maximum dose of morphine and then administer just enough ether to give a semi-narcosis, through which the patient may cooperate with the surgeon in keeping the air passages clear. (3) In performing the operation for vascular tumors affecting the bone, or when for any other reason unusually free bleeding may be expected, it will be advisable to pass a loop of silk about the external or common carotid artery, traction upon which will occlude the vessel, or, if at hand, one of Crile's clamps may be applied. In either case, especial care must be exercised to prevent infection of the wound exposing the artery, as such an occurrence may readily be more serious than the excision of the bone. (4) If there is no reason to expect serious hemorrhage, these precautions become unnecessary. On the other hand, if a more deliberate operation is required, as in cases in which tumors have passed the limits of the maxilla and must be followed in whatever direction they have taken, the advantage of having a dry wound, so that every portion may be inspected without being obscured by blood, cannot be overestimated. In these instances some method of controlling the circulation is of inestimable value.

Septic pneumonia is best prevented by having the nasopharynx treated before the operation by cleansing sprays, douches, and gargles, and by keeping the cavity clean after the operation. Dental sepsis also should be corrected. The patient should be gotten out of bed as early as possible, as early as the second or third day.

Operation.—A number of methods have been devised for resecting the superior maxilla, and many of them have been named after the operator who devised them. The chief variation is in the skin incisions employed to expose the bone, the mode of actually removing the latter being essentially the same in all.

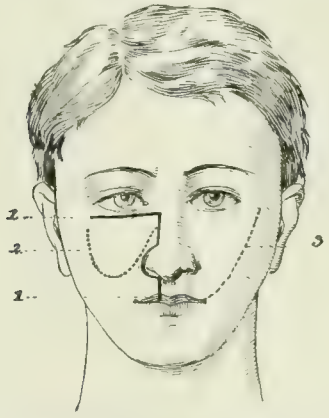

FIG. 2219.—Resection of the Superior Maxilla. 1, The median incision (also called Fergusson's, Nélaton's, Liston's, and Weber's) 2, Langenbeck's incision; 3, Lizars' or Velpeau's incision.

In the classical excision, the incision variously known as the median, Fergusson's, Nélaton's, Liston's, Weber's, etc., is beyond question the best. It gives ample exposure and is followed by less disfigurement than is any other incision. For resections and special cases some of the other incisions may be more suitable.

The incision from the angle of the mouth to the malar bone has been ascribed to Lizars and to Velpeau (Fig. 2219, 3). Langenbeck exposed the bone by a U-shaped flap, beginning at the side of the nose, at the point of junction of the nasal cartilage and bone, and carried downward, outward, and upward, terminating at the middle of the malar bone (Fig. 2219, 2). Liston's incision extended from the angle of the mouth to the external angular process of the frontal bone. Gensoul made three incisions: The first from just below the inner canthus, down the side of the nose, and through the upper lip; a second at right angles to this, on a level with the floor of the nose, as far out as a line perpendicular to the external angular process of the frontal bone; and a third, from the termination of the second to the external angular process. Kocher's incision is a modification of Weber's.

The patient should be placed on his back, with the head and shoulders raised on pillows, the affected side being uppermost. His face should have been cleanly shaven.

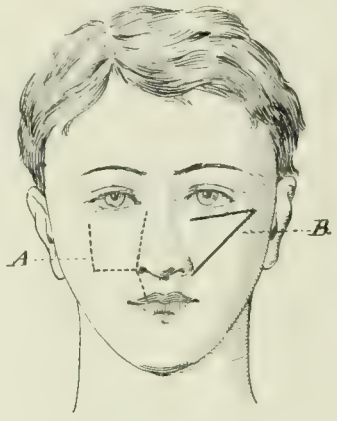

FIG. 2220.—Resection of the Superior Maxilla. *A*, Gensoul's incision; *B*, Langenbeck's incision for osteoplastic resection.

The median incision is made in the following manner: The knife should enter the skin about half an inch below the inner canthus, and the incision should then be carried downward in the line of junction of the nose and cheek to the ala nasi, around and close to the latter, and it should stop just short of the middle line of the lip, from which point it should be extended vertically through the lip to its free border (FIG. 2219, 1). The incision should be carried down to the bone at once, all bleeding points being caught by pressure forceps. Finally, a second incision is to be carried along the lower border of the orbit from the beginning of the first to the malar bone.

The flap thus outlined should be rapidly dissected from the bone, all bleeding points being secured by forceps or by sponge pressure.

At this stage it is well to tie off such forceps as interfere with the subsequent steps, and to arrest all bleeding so far as possible. The malar bone is next divided at about its middle by Hey's saw. If it is proper to leave the orbital plate a second saw cut is made in the line of the second incision, beneath the orbit as far as the nasal process. If the orbital plate is to be removed, the periosteum is incised along the lower border of the orbit and carefully separated from the bone as far back as is necessary, and the floor of the orbit divided at the proper line with a chisel and mallet; or if it is necessary to remove the orbital plate entire, the periosteum is fully separated and it is wrenched from its connections at the time of removing the maxilla.

The nasal bone and nasal cartilage are next separated from the maxilla by means of a saw or chisel. The upper central incisor tooth in the affected maxilla must now be extracted and the mucoperiosteum covering the hard palate divided near the middle line from before backward; the soft palate should also be separated by a transverse incision along the posterior border of the hard palate on the diseased side. By means of a keyhole saw introduced into the nostril

the hard palate is divided in the line of the incision in the mucoperiosteum as rapidly as possible. The bone is then grasped by lion-jaw forceps and wrenched from its remaining attachments, the principal one being the pterygoid process. At this stage the use of the bone-cutting forceps bent at an angle may be required to sever any firm connections. Sponges should be instantly thrust into the cavity and pressure exerted to check the bleeding. The sponges may now be removed one by one, and the bleeding points dealt with by ligation. Usually the hemorrhage will cease after a few moments' pressure. (Fig. 2218, *abc*.)

It will be necessary to pack the wound with gauze which will effectually arrest oozing, but it must not be depended upon to control spurting vessels. Each piece of gauze introduced should have firmly attached a strong thread to assist in its removal. After the operator has assured himself that the hemorrhage is controlled, he should replace the flap and should suture it in position by means of silkworm gut. Especial care should be observed in adjusting the free margin of the lip.

If the bone is much diseased it is apt to break, and must then be removed in fragments. In such cases every portion should be examined for evidences of remaining disease and all such tissue removed. The advantage in leaving the floor of the orbit when possible is that the eye is not disturbed. When it is removed, the eye drops somewhat, and the lower lid is apt to remain red, swollen, and distorted.

The removal of both superior maxillæ becomes necessary in rare instances. The technique is the same as that described above save that it is duplicated on the opposite side.

After-treatment.—The gauze tampon should be removed on the day following the operation unless there is reason to expect free hemorrhage, when it may be allowed to remain another twenty-four hours. The mouth must be kept as clean as possible by the frequent use of washes, douches, and sprays. These should consist of mild antiseptics like solutions of boric acid, salicylic acid, etc. Nourishment during the first few days is maintained preferably by nutrient enemata, and later by milk, broths, and other liquid foods given by the mouth.

Mortality.—This varies in different collections of cases. Butlin in 1887 found the mortality to be about 30 per cent. Bryant's collection (1890) showed 14 per cent. of deaths. Of 66 more or less complete unilateral and 5 bilateral resections, collected by White and Wood (1896), but 6 per cent. died as a result of the operation. The records of St. Bartholomew's, St. Thomas', and University Hospitals, London, have been examined by Butlin (1900), who found 127 cases of excision for malignant disease with 16 deaths (12.6 per cent.). Martens (quoted by Butlin) reports from the clinic of König, in Göttingen, 74 total excisions from 1875 to 1896, with nearly 30 per cent. mortality.

Osteoplastic resection of the superior maxilla is occasionally performed for the purpose of removing nasopharyngeal tumors. Nélaton's method consists in the division of the soft palate anteroposteriorly, and the removal of the posterior half of the hard palate after the mucous membrane and periosteum have been separated from the middle line toward the alveolus on either side. After the removal of the polyp the palate is closed by sutures.

Chalot separated the upper lip from the superior maxilla until the nasal fossæ were opened, then extracted the two upper canine teeth and made an incision through the mucoperiosteum of the hard palate from the point occupied by the extracted teeth, along the alveolus to the posterior border of the hard palate. The alveolus and palate were next divided by a mallet and chisel and the fragment was separated from the vomer and turned down into the mouth, being attached only to the soft palate. After the removal of the tumor the bone should be replaced and held by sutures.

Several methods have been proposed by different surgeons for reaching these tumors for the purpose of excision of portions or all of the bone, the most [illegible] perhaps being that of Rouge. The [illegible] separating the upper lip from the maxillæ by dividing the mucous membrane close to the [illegible] and the alæ are also detached from their [illegible] to the bone and turned upward by inverting the upper lip and making traction. After the removal of the tumor the parts fall naturally into place.

This procedure is suitable for tumors situated anteriorly chiefly. Some means must be adopted for preventing the blood from getting into the [illegible] there is nothing better than intratracheal [illegible]. Langenbeck makes two incisions, one from the [illegible] inner canthus to the malar bone, and another from the nostril to join the outer extremity of the first (Fig. 2220, *B*). The bone is sawed through in the lines of the incisions. The bone still attached to the soft parts is then raised and thrown over on the opposite cheek. The parts are restored and sutured in place after the tumor is removed.

Excision of the Inferior Maxilla. Total, partial, or temporary excisions are done upon the mandible. In *total excision*, the arch is completely divided to some extent, great or little; if this includes the articular portion it is spoken of as a disarticulation. With *resection* the continuity of the arch is preserved and only a limited area, usually the alveolar process, is removed. *Osteoplastic resection*, involves the division of the jaw in such a way as to gain access to the floor of the mouth and pharynx with the subsequent suturing of the bone in its normal position.

In *total excision* the extent and location of the removed bone may vary widely, sometimes a portion may be taken from the horizontal limb, sometimes from the middle section on either or both sides of the symphysis, sometimes half the jaw, and sometimes both halves. When it is necessary to excise near the angle, or to remove half of the jaw, the incision of choice lies externally along the inferior and posterior borders; but in operations upon the middle portions ample exposure with the best cosmetic effect is obtained by a median incision of the lower lip, which may be extended, if necessary, as far as the hyoid bone, or may branch like the two limbs of an inverted Y at the margin of the chin in order to permit of a dissection of the neck. Infrequently, it is possible to avoid all external scar by separating the lower lip and soft parts from the jaw through an incision within the mouth.

There are certain very important points in the technique of operations in this region which should always be remembered. The first of these is the material value of the periosteum, especially in the young, in creating a skeleton frame or form over which new bone may grow. It therefore follows that the bone should be cleaned subperiosteally and with the muscular attachments intact, excepting, of course, in the presence of a malignant neoplasm where the operator must sacrifice all adjacent structures regardless of effect. Another most important necessity is the *immediate* replacement of the resected part by artificial prosthetic means in every case where there is a material solution of continuity. Unless this is done at once, there is apt to follow immediately after the operation danger to life through suffocation, inability to chew, to swallow, or to speak, together with decided disfigurement, while the remote results are scarcely less disastrous by reason of the inward contraction of the stumps and the consequent narrowing of the oral cavity to such an extent, that the later use of apparatus is unavailing. Another factor to be considered arises when the resection affects the forepart of the jaw.

When the geniohyoid and genioglossus muscles are cut at their insertion the tongue is liable to fall back and threaten suffocation to the unconscious patient. This danger should be anticipated and avoided by passing a stout looped suture through the tongue before these muscles are divided. Ordinarily hemorrhage is not a feature of serious moment save perhaps with certain malignant growths. Since with these there is usually required a preliminary dissection of the cervical lymph chains, an opportunity is readily afforded for a temporary or permanent ligation of the external carotid, if deemed necessary. Hemorrhage from the sectioned bone may easily be checked by a plug of bone wax or frayed catgut. In disarticulation care must be taken to avoid injury to the internal maxillary artery as it rounds the neck of the condyle.

The excision of half the jaw is done through an incision which begins at the middle of the chin just below the free portion of the lip, passes downward across its edge and then follows the border of the jaw laterally as far as the angle, where it turns upward along the posterior border of the ramus as far as its middle. This incision is deepened at once to the bone at all points save over the facial artery, which is first isolated and then divided between a double ligature. Working from before backward all the soft parts are raised from the jaw subperiosteally, first on the outer surface and then on the inner as far as the alveolar mucous membrane. The ascending ramus is cleared on its outer surface *only* and the masseter muscle detached from its firm connection with a sharp rugine. In separating the soft parts on the inner side of the jaw care must be taken to avoid injury to the sublingual and submaxillary salivary glands. After cutting through the mucous membrane at the alveolar border, the lower lateral incisor is drawn and the bone is divided by a Gigli or Hey saw, slightly to the involved side of the midline to avoid the genial tubercles. The severed end is seized and drawn outward, permitting the structures on the inner surface of the ramus to be detached without danger at this stage—the internal pterygoid muscle, the inferior dental artery and nerve, the superior pharyngeal constrictor, and the internal lateral and stylomaxillary ligaments. It is then depressed enough to expose the coronoid process, which may be cut at once with bone forceps, or the temporal muscle carefully cut from it with curved scissors. As the jaw is still further depressed the insertion of the external pterygoid muscle appears and is raised, the joint capsule is divided, and the head of the bone is disarticulated forward. The division of the few remaining fibers will free the bone, but caution must be observed at this point that the jaw is not rotated outward lest the internal maxillary artery be hooked over the inner condyle and dragged into the wound and perhaps injured.

When all bleeding has been checked the soft parts are approximated by a few buried sutures, the mucous membrane is carefully stitched with catgut, and the external wound closed with a subcuticular suture to avoid a disfiguring scar. Temporary drainage is necessary at the lower angle of the wound. In the selected case a bone graft—and nothing is better for this purpose than a curved piece of rib—may be firmly contacted with the sectioned end of the remaining half of the jaw and buried in the detached periosteum. Wherever possible, at the time of operation, some attempt should be made to preserve the form of the new jaw which may be created from the periosteum. For this purpose a framework of gutta percha may be fixed in place after the method of Marten of Lyons.

In all degrees of resection between the ascending rami the median incision furnishes the best exposure and the minimum disfigurement. It is with this class of work, where two stumps are left, that the immediate application of measures to prevent contraction and deformity is imperatively demanded. For this purpose internal splints of gutta percha, or gutta percha and metal, or aluminum, or steel must be firmly attached to the ends of the sectioned bone. Whatever splint is used it should not interfere with the new growth of bone, it should preserve the contour of the jaw, it should be cleansable *in situ*, and, finally, it should be removed after the shape of the jaw has been fixed and wound repair has been completed, to be replaced by an artificial plate furnished with teeth. To accomplish all of this to its best effect usually means the cooperation of a dentist.

Resection is usually done for necrosis, for buried roots of teeth after extraction, or for maleruption. Operation is done through the mouth and the diseased area is removed by the curette, gouge, or bone-cutting forceps. Hemorrhage is controlled by gauze packing and if the denuded bone is at all extensive packing may be used for several days. In the majority of cases of necrosis the removal of the sequestrum may be easily accomplished through the mouth. Even where the disease is as extensive as it is in the phossy jaw of the phosphorus worker, sometimes extending from one condyle to the other, external incision is not required and the dead jaw may be lifted from its bed through the mouth. The involucrum in these cases is usually firm enough to sustain the shape of the mandible until osteogenesis forms a new bone, but if there is any doubt upon this point it is well to keep a moulded gutta-percha splint in the wound until it is well healed. In all cases of excision, complete or partial, a painstaking mouth toilet by the frequent use of mechanical cleansing and bland antiseptic washes is imperatively demanded throughout the period of healing, and in many cases the comfort of the patient is greatly aided by tube-feeding during the first week or ten days.

Osteoplastic resection is an operation devised for the exposure of the mouth, fauces, and pharynx by the temporary division of the jaw, which is followed, after the purpose is effected, by suturing of the bone in its place again. The mandible may be divided either in the midline or just in front of the ascending ramus. According to Kocher, the necessity for more than the median section very seldom occurs as ample room may be obtained for practically all purposes by it.

For division of the jaw in the midline, the incision is made directly through the lip, across the edge of the chin, and extends as far as the hyoid bone. After the arteries are caught the entire circumference of the jaw is cleared subperiosteally. A central incisor tooth is drawn and a Gigli saw is passed around the bone. Before the division is made, however, it is well to drill holes on either side of the proposed saw line for the sutures which are to come later. The saw cut should spare the genial tubercles and bevel the bone slightly at the expense of the inner surface. The two sides are now widely separated, preferably by a self-retaining retractor provided with a screw, and the main operation is proceeded with through the gap.

Where the division is made in front of the ramus, the incision extends from the tip of the mastoid process well toward the hyoid bone. The jaw is cleared at the anterior margin of the masseter muscle, after the facial artery is ligated. Preliminary drill holes are suitably placed and the Gigli saw divides the bone obliquely both forward and downward. The severed ramus then may be drawn upward and the horizontal portion forward, thus securing the requisite exposure.

In fixing the fragments much is anticipated prior to division by the correct bevel given to the respective ends so that the tendency to subsequent displacement is minimized, but in addition sutures are required. For this purpose absorbable materials are to be preferred if they are of unusual tensile strength, such as exceptionally strong catgut or kangaroo tendon, but if there is doubt a non-absorbable suture like silver wire may be threaded through the drill

holes and fastened. In either event the periosteum is replaced, the mucous membrane carefully stitched, and the external wound closed by a subcuticular suture. MORRIS BOOTH MILLER.

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The writer has made extensive use throughout this paper, especially in the sections on Excision of the Wrist, Elbow, Shoulder, Ankle, Knee, and Hip, of the article on *Resection of Joints*, by the late DR. FRANK HARTLEY, and of that on *Resection of the Superior Maxilla*, by Dr. Alfred C. Wood, in the second edition of this HANDBOOK.

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Exercise.—The word "exercise" has come into wide use, especially among members of the medical profession, to indicate bodily activity deliberately carried out, without reference to mental exertion, whether the latter be involved or not. Although the graduates of medical schools are made to realize in a vague and general way the importance of abundant outdoor exercise for the maintenance of health, few of them have paid enough attention to physiology to appreciate the relations of the subject to a vital and effective degree; and despite much advertising by the graduates of schools of physical education through their excellent teaching in schools of every kind, many people still fail to realize that physical education is more than "physical culture" in the outworn sense of twenty years ago. The physiology of exercise, now almost a science by itself, is devoted to setting forth and explaining the effects of bodily exercise on the individual in all his aspects—moral, mental, and physical.

EFFECT OF EXERCISE ON GROWTH.—The growth of the individual depends on heredity, nutrition, and exercise, but since these are inseparable we do not know just how much exercise alone has to do with growth. The following principles, however, appear to be involved. Systematic exercise stimulates growth, but growth does not continue for more than a few weeks after stimulation ceases. Increase of weight is due to the formation of fat and the absorption of water. Elaborate chemical analysis is the only method of determining the increase. An ample and varied food supply makes the adolescent taller and heavier, and investigation shows a great difference between the "favored" and ill-nourished types of child. Exercise increases the appetite and stimulates the assimilative processes. Growth is not uniform. Increase in height and weight occur in inverse proportions, that is the greatest increase in weight is not accompanied by equal growth in height and the reverse is also true. The relation of [illegible] tion between action and rest becomes more uniform and tends to be abolished through [illegible] The thorax is developed by exercise to [illegible] the average increase. Growth of the [illegible] becomes more uniform through [illegible] Exercise equalizes growth of different parts [illegible] Heredity determines stature more than [illegible] influence, and is the most important of determinants as illustrated by the "laws" of heredity. [illegible] trition determines increase in weight more than height. Stature is attained at the age of [illegible] years in males, and of eighteen years in females. It is as a rule determined between the twelfth and twentieth years, and exercise taken during this period has the most beneficial influence. In senescence, exercise taken after forty-five tends to prevent the growth of factors that induce senility.

Physical training is growth in respect to physical strength and endurance. It is the raising of the standard in structure and function of motor efficiency. In children, physical training is not advisable. Systematic physical training develops the digestive, assimilative, respiratory, and circulatory systems to meet all the bodily needs. Nutrition, metabolism, and growth are raised to a higher plane of efficiency, and the nervous system is developed along the lines of promptness and certainty, especially by the use of marching tactics which demand prompt reaction and are thus among the most efficient methods for training attention.

By physical training the mechanical apparatus (muscles, tendons, and joints) is enlarged and strengthened. The sarcomeres are distended to their limit by lymph and become hardened. This is an important condition. Dulling of the pain-sense and habituation to minor pains and injuries is a psychological element in the process of physical training. Training, however, is often overdone in many ways, *e.g.* through diet, an expensive training table, trainers, and overexertion. All that is needed is an ample non-fat-producing diet, and one that will not disarrange the digestive apparatus. As a rule there is more disturbance of digestion when a man is under a course of severe mental training. Most of the evil effects of training are due to overtraining, especially of the heart. Then, when training stops degeneration takes place in the unused muscle-masses of the heart and evil results follow. Many are certainly overtrained to a harmful degree.

The researches of Burge (reported by Graham Lusk, in the *Archives of Physiology*, 1900) on the effects of training on mountain climbers in Switzerland, showed a total loss per kilo of body weight in carbon dioxide, the index of metabolism, as follows:

Trained Men.	Untrained Men.
2.10 grams.	2.4 grams.
2.27 grams.	2.71 grams.
2.06 grams.	2.25 grams.
2.21 grams.	2.44 grams.

Obviously the untrained individual was at a disadvantage. The greatest difference between the two types was shown at an altitude of 3,000 meters.

EFFECTS OF EXERCISE ON NUTRITION. Lack of exercise permits the accumulation of fat in the body. Pathologically, obesity is a disease. Some are born fat; others achieve fatness (laziness); and others have fatness thrust upon them (inability to exercise). Physiological obesity is a matter of lack of balance between food and work. The proper amount of exercise maintains tonicity of the entire system; and superfluous fat is kept out of all the muscles and organs.

Londe (1860) experimented on two dogs giving full meals to both and immediately afterward [illegible]

exercise violently, while the other was in complete rest. After two hours, the intestines of the first were found to contain food, although the digestive process had not begun. After the same period food in the process of digestion was found in the stomach of the second dog. Moderate exercise after a meal may, therefore, be considered not harmful.

Constipation, which may be due to a variety of causes, may be cured by systematic and proper exercise. Exercise increases heart action, respiration, absorption, assimilation, and elimination. The movements of the diaphragm become more complete and exert a vigorous and rhythmical massage on the large intestine. The liver and the gall-bladder also are benefited. Peristalsis is increased through increased tonicity of the nerve centers and the increased flow of secretion from the glands softens the feces. The strength of the vegetative muscles is greatly increased by systematic exercise.

There is no evidence that moderate exercise exerts any evil influence on the digestive processes. The excretion of nitrogen is apparently not increased after exercise. No difference in the thoroughness of digestion was noted in the same subjects when at rest or when hill cimbing; and observations on dogs have shown that, beyond a delay in the secretion of pepsin, exercise after eating was apparently without effect. Food consumption in the dogs did not increase through exercise, and the protein catabolism was somewhat lessened. It may be concluded, therefore, that while violent exercise may impede, moderate exercise has no effect upon digestion.

Sugar, being an immediate muscle food has been proved to be the best food during excessive muscular work, though it should not be taken to excess or near regular meal times. Through its use the heart may be regulated and brought to a good condition. Its value as a muscle food is shown in an experiment carried out on two English boys, who for two months practised rowing for five hours daily and during that time were fed on five ounces of sugar each day. At the end of this training period both won from trained competitors who had not been fed on sugar. It has been estimated that the ingestion of 17.5 ounces of sugar increases the active power of work from 61 to 70 per cent.

Effect of Exercise on the Nervous System.—These effects are by far the most important, the least obvious, and the most difficult to demonstrate. Exercise gives more benefit to the nervous system than to any other organ. It is estimated that the human cortex of from thirty to forty grams weight contains 3,000,000,000 to 6,000,000,000 nerve cells. Exercise involving a combination of the large muscles results in an extreme degree of neuromuscular coordination which induces gracefulness, skill, and strength by giving better voluntary control. All this depends upon the relation of the neurones and the complexity of the nervous system which is due to the increase of neurites, development of collaterals, etc. On the average there are twenty muscle fibers to one motor neurone; in the eye there are five muscle cells to one neurone; in the gluteus maximus fifty muscle fibers to one neurone; and as the muscles increase in skill the neurones increase proportionally. The vasomotor system is enlarged through exercise and a better adaptation of the blood supply results. Exercise develops the kinesthetic (muscle and joint) sense, an important factor in the treatment of the feeble-minded. Forbes has shown that muscle fatigued through one afferent path can be stimulated into action through another; and exercise is thus a means of using and stimulating muscle groups through all the available sensory and afferent pathways. It improves the nutrition of the nervous system, stimulates the circulation, and increases the mental ability. The brain was developed as a motor organ and deliberate exercise is, therefore, now more and more necessary in order that it may be kept in good condition. The first eight years of life should be wholly devoted to the development of the neuromuscular system. Lack of exercise, because of the resulting poor physical tonicity increases sensibility to pain and injuries, and the results of college football training may be cited as an extreme instance of reverse conditions. The nervous system works in a rhythm with periods of efficiency and inefficiency, and exercise tends to abolish the rhythmical moods thus induced.

The effects of exercise on the nervous system may be enumerated as follows:

1. Exercise helps to make more complete the integrating function of the nervous system which in the last analysis is the latter's sole office.

2. The second effect of physical exercise upon the nervous system lies in an invigoration of the nerves through the production of a larger amount of chromatin in the nerve cells. Physical exercise increases the amount of chromatin in the cell nucleus and so serves to make the action of the cells more vigorous by furnishing more energy to the nervous impulse.

3. The third effect of physical exercise upon the nerves is in the development and invigoration of the vasomotor system in regard both to its action and to its function, so that the nerve centers when they require it obtain a more abundant supply of blood.

4. A fourth effect of physical exercise lies in the improved nutrition of the nervous system; the circulation is stimulated, and the brain is flushed out more rapidly. Attention has been called to the increased flow of lymph through the organism as one of the chief causes of the improvement in the efficiency of the individual following physical exercise.

5. The nervous system may also be benefited by the production through exercise of large amounts of hormones, chemical substances produced in one part of the body for use in another part. For instance, the secretion of the hypophysis cerebri, which probably has vasomotor connections and exerts a powerful influence over vasomotion and so over blood pressure, seems to be employed in maintaining the proper nutrition of some of the tissues of the body and perhaps the nutrition of parts of the nervous system.

6. It is a true saying that health comes in by the muscles and flies out by the nerves, and in this connection one may consider the different conditions existing in a manufacturing town of to-day from those of perhaps sixty years ago, comparing the amount of exercise obtained by the workers of that time when all the industries were carried on by hand, with that of a man in a shoe factory of to-day, for instance, where each man does perhaps only one-eighty-first part of the process necessary for the completion of a shoe. The effect of this lack of physical exercise on those engaged in such occupation is seen in the nervous system. In the first place, the nervous systems of such individuals are undeveloped owing to their lack of variety of movements; in the second place, their nervous systems are overworked in those particular parts which they must use in carrying out their work; an example of this is seen in writer's cramp. Such individuals are under a nervous strain, and this nervous strain is usually accompanied by a disturbance in the coordinating centers of the nervous system. Some exercise is needed by many men and women whose work is physically too narrow. (Stanley Hall.)

7. In addition to the effects already enumerated, physical exercise has another influence upon the nervous system; that is, the lessening of hyperalgesia or excessive sensitiveness to pain and hyperesthesia, or excessive sensitiveness of the nervous system. Physical exercise more than any other normal means lessens the effect of the sensitivity of the nervous

system, and especially sensitivity to pain and feeling in general.

8. Another effect of systematic physical exercise upon the nervous system is the shortening of the reaction time; and anything that shortens reaction time is helpful and beneficial to an extreme.

9. A normal amount of pure muscular exertion is the best aid to natural sleep.

10. The whole sympathetic nervous system is indirectly developed by physical exercise; this is an important thing, for the sympathetic system (underlying vegetative functions and processes of the organisms) is the chief determinate of the individual's efficiency.

11. Another effect of physical exercise upon the nervous system lies in the development of the kinesthetic receptors for it must be supposed that exercise increases the number of kinesthetic end-organs in the muscles, joints, tendons, and bones.

12. Still another mode in which the nervous system may possibly be developed by systematic exercise lies in the development of the motor end-plates. This last, however, is purely a supposition, but serves to complete the logical demonstration of the effects of physical exercise upon the nervous system.

Effects of Exercise on the Circulation.—Exercise may be considered in relation to (1) heart rate, (2) regularity of heart beat, (3) size of heart, (4) relation of systole and diastole, (5) amount of blood, (6) pressure of blood, (7) vigor of heart and arteries.

The *heart rate* is always increased by active exercise, but is not affected by passive movements and massage. It is probable that the heart rate is not a reflex and that its control is from the medulla oblongata, and not from the periphery of the body. A rapid return to the normal rate is an indication of good accommodation and training. In well-trained men the return is rapid, occurring often in fifteen seconds. The same is true of blood pressure. In men who are physically well developed a slow pulse is usually found.

Regularity of Heart Beat.—Cook and Pembrey have shown that heart beats may be dropped without any disturbances of rhythm. The action is apparently similar to that of apnea in respiration. In an untrained heart the irregularity shows in the volume and rate of the pulse which is sometimes fast and again slow. Hill has shown that the maximum efficiency is reached when the heart rate is 150 per minute. The so-called "second wind" is due to cardiac influences and fatigue antitoxins.

Size of Heart.—There are two types of changes: (1) hypertrophy of normal growth; (2) dilatation. The heart may increase in all directions, as in pregnancy; the hypertrophy is normal and unavoidable, being the adaptation of the heart to increased demands. A distinct line must be drawn between dilatation and hypertrophy. In the former there is no increase but only a stretching of the tissues, and there is lessening of the elasticity; whereas in hypertrophy the entire organ is enlarged and strengthened. Adolescents should not be allowed to indulge in heavy muscular competition, such as basket-ball, rowing, long distance running, or any exercise in which the strain is long continued. Recent research suggests that heart leak is a safety valve. The chordæ tendineæ of the papillary muscles serve to protect and release the strain on the valves. Under fatigue they relax and permit leakage causing regurgitation to the auricles. Heart murmurs are of little importance after exercise provided they disappear in normal time.

Relation of Systole and Diastole.—The normal rate is about seventy-five per minute. In exercise there is first, a lengthening of the ventricular systole; second, a gradual shortening as exercise proceeds; third, a gradual lengthening to normal. Systole to diastole is as one to three at [illegible] after exercise, however, the diastole is much shorter. The periods almost equalize, showing how the rest period is decreased. The same result comes from the use of alcohol.

Amount of Blood.—A distinction must be drawn between amount and pressure. An organ may receive a larger amount at low, less blood at high, pressure. The size of the arteries, the heart rate, the size of the heart, the strength and vigor of the ventricular systole, the elasticity of the arteries, and osmosis from the capillaries, all determine the amount and pressure of blood. The physical balance of the amount and the pressure is not yet known.

Blood Pressure.—Exercise, systematic and adequate, normalizes the blood pressure, as it does all the other functions. If blood pressure be low because of an undeveloped heart, exercise tends to raise it somewhat to a certain normal maximum of efficiency, about 120 millimeters of mercury. No one other thing seems to represent the general bodily condition of a person, as well as the time required after exertion, bodily or mental, for the blood pressure and the heart rate to return to their previous states.

Force of Heart.—This may be considered in relation to dilatation, hypertrophy, and degeneracy. The hypertrophied heart is always strong and forceful; the dilated heart is always weak and uncertain; the degenerated heart weak, uncertain, and dangerous. With increasing age the conditions become more critical.

Effect of Exercise on Body Heat and Work.—Muscular exercise of average amount or moderate degree always raises the temperature a little, while active muscular exercise raises it from one to two degrees. The rectum is the only reliable place for taking temperature, as the heat end-organs of the skin are always much warmer, and the mucous membrane of the mouth is cooler through evaporation. After a ride of one hour the temperature of Boyd, static bicycle rider, rose from 98.6° to 99.7°, returning to normal after a half-hour's rest. Sixteen men and boys after one hour's exercise showed a maximum increase of 0.5° C.; after mountain climbing, 1280 meters, there was an increase of 1° C. In an observation on Marathon runners it was found that as a result of the overexercise, the rectal temperature fell from one to two degrees, due to the lowering of tonicity and metabolism. These men, showed in addition, an average loss in weight of four pounds, mostly by evaporation.

In general, the right amount of exercise develops efficiency, strength, promptness, and tirelessness. Quickness of recovery of normal function is a criterion of the efficiency of an organ. Walking is the most important of all exercises, since two-thirds of the body muscles are concerned in it. With oxygen consumption taken as an index observations were made to determine the most economical step; the experiment was started at seventy-six steps per minute and increased to 130 at which point the oxygen consumption fell, it being then determined that this was the most economical step, and that a higher or lower rate was more expensive to the body. At this rate the carrying of a burden does not materially decrease efficiency. The gastrocnemius and soleus through leverage on the os calcis, maintain a rhythmic alternation of raising and lowering of weight. The average rise in height in walking is fifteen millimeters. Walking, therefore, is not an extravagant exercise. In running there is extreme strain, due to extension of the legs and forcing of the body weight over them. Dancing is an important exercise; it embodies all the factors of walking, and endless variations, from the stately minuet to athletic dancing.

Excessive Exercise.—[illegible] can be severe and of long duration with almost no

limit to the amount of exertion. It must be very heavy to be physiologically excessive; so severe and terrific that there is actual wear and tear. College athletes are as a rule far overtrained. A mild subacute fever and condition of stiffness are felt after excessive exercise; in severe cases the constitutional symptoms are malaise, insomnia, loss of appetite, and an increase of temperature of one degree. The causes of these conditions are: (1) chemical toxemia, (2) wear and tear. The toxemia is caused by a catabolic protein produced by overuse of the muscles; urates are found in the urine, which is highly colored and concentrated, with a trace of albumin. The sarcolatic acid in the blood is increased 630 per cent., and there is an increase also in the muscles; phosphates are also increased. Absorption of toxin causes fever; wear and tear causes soreness in this condition. Turnfieber can be avoided by following the common sense rules of psychophysical hygiene.

Muscle, biologically, is primitive tissue. It is the most healthy of the entire organism, and the least apt to be diseased. Michael Foster claimed it as the "master tissue," and it is by all means the most complex, representing movement, the fundamental essence of all life in its material aspects.

Few persons really more need to have effective knowledge of these matters, for use both on their patients and on themselves, than do physicians, little as they as yet realize the fact.

GEORGE V. N. DEARBORN.

Exophthalmic Goiter.—See *Goiter, Exophthalmic.*

Exostoses.—See *Periosteum, Tumors of.*

Expectorants are medicines that are used in catarrhal affections of the larynx, trachea, and bronchi, to modify secretion and facilitate the removal of morbid products. As a group-term this word seems to be disappearing from modern therapeutics. Its current literature, for the past twenty years, has been extremely scanty, and no monograph exists on the subject. Expectorants are at present largely viewed as necessary evils, if indeed necessary at all. Not a few standard works on therapeutics exclude the term outright, along with some of its fellows. A very large number of drugs have expectorant properties, but when they are prescribed it is usually as adjuncts to more or less powerful sedatives, like heroine, codeine, morphine, chloroform, or hydrocyanic acid. No valuable new expectorant has been added to the practitioner's armamentarium within recent years. The new laws against selling proprietary medicines containing drugs which cause addictions, or are dangerous, naturally tend to show up the inferiority of mixtures of mere expectorants.

EDWARD PREBLE.

Expectoration.—See *Sputum.*

Extracta.—An extract (*extractum*) is a preparation of solid or semi-solid consistence, in which the crude drug is acted upon by a solvent, generally alcohol or diluted alcohol, and the resulting solution is evaporated down to the proper consistence. Extracts are of varying consistence, some being sufficiently hard to admit of pulverization, while others—and, indeed, the majority—are semi-solid in consistence, and of just the right degree of stickiness to permit of ready rolling into pills. Extracts are, for this latter reason, very commonly prescribed in pill form. In the United States Pharmacopœia there are twenty-eight extracts; in the British Pharmacopœia, twenty-two; and in the National Formulary, twelve.

		Dose
EXTRACTUM ACONITI	N. F.	
EXTRACTUM ALOES	U. S. P.	Gr. 2 (0.125 gm.).
EXTRACTUM ALOES BARBADENSIS	B. P.	Gr. 1 to 4 (0.065 to 0.250 gm.).
EXTRACTUM ANTHEMIDIS	B. P.	Gr. 2 to 8 (0.125 to 0.500 gm.).
EXTRACTUM ARNICÆ RADICIS	N. F.	
EXTRACTUM BELLADONNÆ ALCOHOLICUM	B. P.	Gr. ½ to 1 (0.015 to 0.065 gm.).
EXTRACTUM BELLADONNÆ FOLIORUM	U. S. P.	Gr. ½ (0.010 gm.).
EXTRACTUM BELLADONNÆ VIRIDE.	B. P.	Gr. ¼ to 1 (0.015 to 0.065 gm.).
EXTRACTUM CANNABIS INDICÆ	U. S. P.	Gr. ⅛ (0.010 gm.).
EXTRACTUM CANNABIS INDICÆ	B. P.	Gr. ¼ to 1 (0.015 to 0.065 gm.).
EXTRACTUM CASCARÆ SAGRADÆ.	B. P.	Gr. 2 to 8 (0.125 to 0.500 gm.).
EXTRACTUM CIMICIFUGÆ.	U. S. P.	Gr. 4 (0.250 gm.).
EXTRACTUM CINCHONÆ	N. F.	
EXTRACTUM COLCHICI	B. P.	Gr. ¼ to 1 (0.015 to 0.065 gm.).
EXTRACTUM COLCHICI CORMI	U. S. P.	Gr. 1 (0.065 gm.).
EXTRACTUM COLOCYNTHIDIS	U. S. P.	Gr. ½ (0.030 gm.).
EXTRACTUM COLOCYNTHIDIS COMPOSITUM.	U. S. P.	Gr. 7½ (0.500 gm.).
EXTRACTUM COLOCYNTHIDIS COMPOSITUM.	B. P.	Gr. 2 to 8 (0.125 to 0.500 gm.).
EXTRACTUM CONII	N. F.	
EXTRACTUM DIGITALIS	U. S. P.	Gr. ⅛ (0.010 gm.).
EXTRACTUM ERGOTÆ	U. S. P.	Gr. 4 (0.250 gm.).
EXTRACTUM ERGOTÆ	B. P.	Gr. 2 to 8 (0.125 to 0.500 gm.).
EXTRACTUM EUONYMI	U. S. P.	Gr. 2 (0.125 gm.).
EXTRACTUM EUONYMI SICCUM	B. P.	Gr. 1 to 2 (0.065 to 0.125 gm.).
EXTRACTUM FERRI POMATUM	N. F.	Gr. 10 (0.650 gm.).
EXTRACTUM GENTIANÆ	U. S. P.	Gr. 4 (0.250 gm.).
EXTRACTUM GENTIANÆ	B. P.	Gr. 2 to 8 (0.125 to 0.500 gm.).
EXTRACTUM GLYCYRRHIZÆ	U. S. P.	Gr. 15 (1.000 gm.).
EXTRACTUM GLYCYRRHIZÆ	B. P.	
EXTRACTUM GLYCYRRHIZÆ DEPURATUM.	N. F.	Gr. 15 (1.000 gm.).
EXTRACTUM GLYCYRRHIZÆ PURUM.	U. S. P.	Gr. 15 (1.000 gm.).
EXTRACTUM HÆMATOXYLI	U. S. P.	Gr. 15 (1.000 gm.).
EXTRACTUM HYOSCYAMI	U. S. P.	Gr. 1 (0.065 gm.).
EXTRACTUM HYOSCYAMI VIRIDE.	B. P.	Gr. 2 to 8 (0.125 to 0.500 gm.).
EXTRACTUM IRIDIS	N. F.	
EXTRACTUM JALAPÆ	B. P.	Gr. 2 to 8 (0.125 to 0.500 gm.).
EXTRACTUM JALAPÆ	N. F.	
EXTRACTUM JUGLANDIS	N. F.	
EXTRACTUM KRAMERIÆ	U. S. P.	Gr. 7½ (0.500 gm.).
EXTRACTUM KRAMERIÆ	B. P.	Gr. 5 to 15 (0.325 to 1.000 gm.).
EXTRACTUM LEPTANDRÆ	U. S. P.	Gr. 4 (0.250 gm.).
EXTRACTUM MALTI	U. S. P.	℥ 4 (16.000 c.c.).
EXTRACTUM NUCIS VOMICÆ	U. S. P.	Gr. ¼ (0.015 gm.).
EXTRACTUM NUCIS VOMICÆ	B. P.	Gr. ¼ to 1 (0.015 to 0.065 gm.).
EXTRACTUM OPII	U. S. P.	Gr. ½ (0.030 gm.).
EXTRACTUM OPII	B. P.	Gr. ¼ to 1 (0.015 to 1.065 gm.).
EXTRACTUM PHYSOSTIGMATIS	U. S. P.	Gr. ⅛ (0.008 gm.).
EXTRACTUM PHYSOSTIGMATIS	B. P.	Gr. ¼ to 1 (0.015 to 0.065 gm.).
EXTRACTUM PODOPHYLLI	N. F.	
EXTRACTUM QUASSIÆ	U. S. P.	Gr. 1 (0.065 gm.).
EXTRACTUM RHAMNI PURSHIANÆ.	U. S. P.	Gr. 4 (0.250 gm.).
EXTRACTUM RHEI	U. S. P.	Gr. 4 (0.250 gm.).
EXTRACTUM RHEI	B. P.	Gr. 2 to 8 (0.125 to 0.500 gm.).
EXTRACTUM SCOPOLÆ	U. S. P.	Gr. ⅛ (0.010 gm.).
EXTRACTUM STRAMONII	U. S. P.	Gr. ⅛ (0.010 gm.).
EXTRACTUM STRAMONII	B. P.	Gr. ¼ to 1 (0.015 to 0.065 gm.).
EXTRACTUM STRAMONII SEMINIS	N. F.	
EXTRACTUM STROPHANTHI	B. P.	Gr. ¼ to 1 (0.015 to 0.065 gm.).
EXTRACTUM SUMBUL	U. S. P.	Gr. 4 (0.250 gm.).
EXTRACTUM TARAXACI	U. S. P.	Gr. 15 (1.000 gm.).
EXTRACTUM TARAXACI	B. P.	Gr. 5 to 15 (0.325 to 1.000 gm.).
EXTRACTUM UVÆ URSI	N. F.	

R. J. E. SCOTT.

Extrasystole.—See *Arrhythmia, Cardiac.*

Extrauterine Pregnancy.—See *Gestation, Ectopic.*

Exudation, Pathological.—One of the chief phenomena of inflammation is the passage of a portion of the fluid and cellular constituents of the blood from the blood-vessels into the tissue spaces or out upon one of the free surfaces of the body. This process is known as *exudation*, and the fluid and cells which have left the vessels as an *exudate*. Inflammations in which the passage of fluid and cellular elements of the blood from the blood-vessels predominates over the other phenomena of the inflammatory process are called *exudative inflammations*. *Exudation* is usually distinguished from *transudation* in that it is always a part of an inflammatory process, while the latter term is commonly restricted in its application to an increase in the formation of lymph not due to inflammation, but dependent upon changes in blood pressure, alterations in the blood, or in the vessel wall which favor an increased lymph production (edema). No sharp line can be drawn between them, either clinically or pathologically in so far as their chemical constitution is concerned. *Exudates* as a rule differ from *transudates* in their higher albumin content, higher specific gravity (1.016–1.025), and their greater richness in cellular elements. Transudates have a low specific gravity (1.006–1.008, rarely reaching 1.012), contain but few cells, and differ but little in their composition from that of normal lymph, their albumin content being very slight, sometimes lower and sometimes slightly higher than that of lymph. Transudates rarely contain fibrinogen, exudates are usually rich in this constituent. The salt-content of both is usually that of blood serum, but may be higher; other soluble substances such as sugar, urea, cholesterin, mucin-like substances, etc., may be found in both. Proteolytic enzymes and various antibodies may be found in exudates as well as bacterial and protein poisons. Exudates are usually turbid from the large number of leucocytes contained in them, while transudates are usually clear or but slightly cloudy. The most important point of differentiation between simple transudates (*edema*) and inflammatory exudates is the presence or absence of signs of inflammation (smooth, shining translucent serous surface when there is no inflammation; cloudy, roughened, injected serous surface showing small hemorrhages or fibrinous deposits when the process is inflammatory).

The source of both the fluid and the cellular constituents of exudates is the blood, and the escape of these from the vessels is due to some alteration in the vascular walls which forms an essential part of the inflammatory process. Evidences of this alteration are seen in the dilatation of the vessels, the increased resistance offered to the blood current with consequent slowing of the circulation, the increased adhesion of the cellular elements of the blood to the vessel wall, and, most important of all, the increased permeability of the walls. The composition of the exudate is therefore dependent upon the degree of pathological alteration as well as upon the peculiar property of the affected vessel. The greater the injury the greater the exudate and the amount of albumin and cellular elements contained in it. Moreover, since the properties of the blood-vessel walls differ in different regions of the body, the character of inflammatory exudates in different parts will also vary; thus the albumin content of pericardial and pleural exudates is higher as a rule than that of peritoneal. Exudates differ further in the proportionate amounts of the various blood elements contained in them. In one case the exudate may be almost entirely fluid with a very small number of cells (serous exudate); in another, the leucocytes may be so numerous as to give the exudate a more or less thick, creamy appearance (purulent exudate); or the escaped fluid may contain large amounts of fibrinogen and fibrin ferment (fibrinous exudate). On mucous membranes the exudate may contain mucus arising from a degeneration of the mucous glands or epithelium (*catarrhal*, *mucous*, or *mucopurulent*). Further, many red blood cells (*hemorrhagic exudate* or diapedesis hemorrhage) and blood plates may be present in the exudate. Combined characteristics exist, so some exudates may be properly styled serofibrinous, seropurulent, purulent, etc. Besides the blood constituents inflammatory exudates also contain [illegible] arising from cellular hyperplasia and degeneration, etc. The high proportion of albumin in many exudates is due partly to proteids derived from tissue destruction. In exudates there may be contained the poisons arising from tissue destruction or, in infective inflammations, from the growth of microorganisms; the bacteria themselves, and cells arising from the proliferation of fixed cells of the tissue, may likewise be present.

The various problems regarding the manner of escape of the exudate from the blood-vessels have offered abundant scope for investigation and speculation, and a survey of the various theories evolved to solve these problems forms one of the most interesting historical chapters in the development of pathology. The existence of pathological exudates was very early recognized. Rokitansky believed that they arose from an increased permeability of the wall of the vessels due to thinning from overdistention. Vogel, Paget, and others explained their formation as being due to an increased attraction between the tissues and the elements of the blood. Virchow distinguished two kinds of exudates: one the result of mechanical pressure in the vessels, pressed-out blood serum; the second as nutritive, the result of an increased attraction between the tissues and blood constituents. The cellular portion of the exudate he believed to originate from a proliferation of the tissue cells in the inflamed area.

Dutrochet in 1842 and Waller in 1846 first observed the migration of leucocytes from the vessels, but these observations were forgotten until Cohnheim in 1867 rediscovered the phenomenon. This observer affirmed that the passage of leucocytes from the vessels formed the essential feature of inflammatory exudation; that the cells in inflamed areas did not arise from the tissue cells; and he explained the origin of the fluid portion of the exudate as due to a molecular change in the vessel wall. This view was opposed by many, notably Stricker, who held that the greater part of the cells in inflammatory exudates were not leucocytes but new cells arising out of the inflamed tissue, pus cells therefore taking their origin from connective-tissue cells.

Heitzman believed also that the cells of the exudate were not leucocytes, but were embryonic cells arising from the softened or dissolved intercellular substance. More recently Grawitz has taken a similar position, in that he declares the cells of the exudate to arise from so-called "slumbering cells" in the intercellular substance of connective tissue which under normal conditions are not visible. The views of Stricker, Heitzmann, and Grawitz find little acceptance at the present time, the almost universally accepted opinion being that the chief part of the cells of inflammatory exudates at least arises from the blood.

Heidenhain explains the formation of lymph as a process of secretion on the part of the cells of the vessel walls and not as a pure filtration process. Pathological stimulation of this process or alterations in the vascular walls will change the amount and character of this secretion. A portion of the fluid of exudates at least must be regarded as being of the nature of a pathological cell secretion. According to Arnold, Thoma, and Engelmann the formation of the exudate is due chiefly to changes in the lines of cement substance lying between the endothelial cells of the ves-

sel wall. Through distention of the vessel the cement substance may be so thinned as to form small openings through which both fluid and cellular elements escape. Other writers hold that the escape of the leucocytes is not due to alterations in the vascular walls but to chemotactic influences acting from outside of the vessels and causing the cells to pass through the wall.

At the present time the exact nature of the process by which exudates are formed cannot be said to be definitely fixed. The most commonly accepted view is that the chief part of the fluid and cellular elements comes from the blood, and that both pathological secretion and alterations in the wall, as well as chemotaxis, play parts in the formation of the exudate. The escape of the leucocytes is generally considered an active process brought about by means of their ameboid power in response to chemotactic stimuli. Against this view is the fact that in many inflammations lymphocytes, red blood cells and blood plates also escape from the vessels into the tissues. Lubarsch and others hold that the escape of both fluid and cells is purely passive, that as the result of the increase of pressure in the blood-vessels, and the greater permeability of the wall fluids and cells are forced out of the vessels. Schridde is one of the most recent writers to affirm that chemotaxis is the chief factor in the migration of the leucocytes from the vessels. Chiari and Jannuschke have shown that the formation of transudates and exudates can be inhibited by calcium salts. It follows from the results of their experimental work that the chemical-physical conditions of the vessel wall are of the greatest significance in the formation of exudates. In the very earliest stages of the inflammatory process the cells of the exudate are wholly leucocytes; later, tissue proliferation begins and a part of the cells of the exudate may thus be derived from tissue cells.

Much attention has been given to the closer study of the leucocytes found in exudates. Lubarsch divides the cells of inflammatory exudates into hemotogenous wandering cells and histiogenic wandering cells, in the former case descendants of immigrated cells, in the latter arising from fixed connective-tissue cells. The relative proportion of these cells varies in different forms of inflammation, and in different stages of the same form; but the immigration of leucocytes forms the most prominent feature of the majority of inflammations. Until recently it was affirmed that the migrating leucocytes were chiefly polynuclear forms and that these only possessed the power of active movement. Welch, Councilman, and others have shown that lymphoid cells may also migrate, a fact which was formerly denied. The so-called plasma cell also appears to play an important rôle in many exudates, particularly those of chronic inflammation. These cells are regarded in part as derivatives of lymphocytes, and in part as of connective-tissue origin. The plasma cell is characterized by a protoplasm staining blue with methylene blue, an eccentrically placed nucleus, a perinuclear clear space, and a nucleus possessing a number of coarse particles of chromatin arranged on the inner surface of the nuclear membrane. Plasma cells occur in large numbers in the cellular exudate of chronic inflammations, particularly, as Councilman has shown, in the interstitial nephritis of scarlatina. This observer believes that they are lymphocytes which migrate as such or as plasma cells from the blood, and multiply outside of the vessels in response to chemotactic stimuli. It would appear, then, that there are selective chemotactic stimuli; part influencing the migration of lymphoid and plasma cells, part the polynuclears or other varieties of leucocytes. Some exudates contain large numbers of eosinophiles and mast cells, but the significance of such occurrence is not yet known. It is still a question whether the large numbers of cells with eosinophile granules seen in some inflammatory exudates and infiltrations came from the blood as such or are formed in the tissues outside of the vessels. As a rule the eosinophiles do not appear in the early stages of the inflammatory process. Leucocytes with basophile granulation appear in chronic exudative inflammations but not in acute ones. The klasmatocytes of Ranvier are also found in the exudate of chronic inflammations.

Wieniarski confirms the assertion of Korczynski and Wernicki that lymphocytes predominate in exudates not due to malignant disease or showing a tendency to become purulent. When neutrophile polynuclears predominate the exudate is caused either by malignant disease or by pus-forming agents. According to these observers the presence of eosinophile cells and red blood cells in exudates is without significance. In pleural and peritoneal transudates the cells are almost exclusively lymphocytes; in pleural exudates of serous nature they are also lymphocytes; the predominance of polynuclears always indicating a purulent process in case no malignant disease is present. In one case in which but few leucocytes were present in the exudate, but these all polynuclears, a purulent exudate developed later; in another case in which 6,230 lymphocytes were present in a cubic millimeter of the exudate the inflammation did not become purulent in character. The same facts apply also to peritoneal exudates. In serous pleural exudates the number of lymphocytes varies from 270 to 9,270 per cubic millimeter, in transudates from 60 to 300. In peritoneal transudates even smaller numbers of lymphocytes are usually present. During the absorption of exudates the number of leucocytes increases; during fibrinous exudation they are found in smaller numbers. In a general way it may be said that polynuclear neutrophile leucocytes predominate in severe and rapidly developing inflammations, while lymphocytes are the more abundant the more slowly the inflammation develops. Much work yet remains to be done along this line, as many important problems regarding the fate of the migrated cells have yet to be settled.

The fluid and cellular exudates from the vessels collect first around these, but soon spread into the lymph spaces of the neighboring tissues forming an infiltration. If the exudate is very abundant the neighboring healthy tissue may be infiltrated to such an extent that it may be damaged and the inflammatory process spread. The tissue elements may absorb a portion of the exudate, and become swollen or vacuolated; or all of the tissues may become dissolved in the exudate. If fibrinogen and fibrin ferment are present, coagulation may take place either before or after liquefaction of the affected tissue takes place. Open spaces in the tissues, such as the lung alveoli, may become filled with the exudate; if the inflammation involves a body surface the exudate may either collect in one of the body cavities or be discharged from a free surface.

The first pathological changes which find expression in the formation of a pathological exudate are vascular phenomena which are due either to irritation or paralysis of the vasomotor system, or to a direct action upon the walls of the vessels themselves, the result in either case being a dilatation of the vessel. This change may, however, take place without the production of an exudate, but it always precedes exudate formation when the latter occurs. Following the dilatation of the vessel there is a slowing of the blood stream and with this a marginal collection of the leucocytes along the vessel wall; and finally diapedesis of the cellular elements takes place simultaneously with the passing out of the fluid portion of the exudate. The latter is in part a filtration-process, and in part a vascular secretion. The passage of the leucocytes is probably an active process accomplished by means of ameboid movement, and is only an increased degree of a process which takes place to a limited extent normally (wandering cells). The cause of the increased di-

apedesis of leucocytes in inflammation is probably partly chemotaxis and partly changes in the vessel wall. According to Arnold and Thoma the leucocytes pass through the endothelial cement substance which is stretched and thinned by the distention of the vessel. The leucocyte first sends a process through the thinned portion of the wall, and through the opening thus made the remainder of the cell body slips after. Through the opening formed in this manner the red blood cells and fluid elements of the blood may also pass. The more severe the alteration of the vessel wall the more marked the exudative process.

The passage of a serous exudate into a body cavity, as the pleural or peritoneal, is spoken of as a *serous effusion*. Serous exudates on mucous membranes are styled catarrhs; localized collections of fluid beneath the horny layer of the skin are *blisters, vesicles, bullæ*, or *blebs*. The serous infiltration of tissue spaces is an *inflammatory edema*. On mucous surfaces serous exudates may contain a large percentage of mucin derived from mucous degeneration of the epithelium (mucous catarrh); or a loosening of the epithelium into the exudate may occur (desquamative catarrh). If flakes of fibrin are formed in the exudate it may be styled serofibrinous; if the number of leucocytes is so great as to make the fluid slightly turbid, seropurulent. Serous exudates are often but transitory stages of inflammatory processes that later take on a purulent or fibrinous character.

Fibrinous exudates occur either upon mucous or serous surfaces, into the lung alveoli, or into tissue spaces. On mucous membranes they form whitish or grayish croupous or diphtheritic pseudomembranes which are either loosely or firmly adherent to the tissues beneath. These pseudomembranes are made up chiefly of granular or fibrogranular fibrin, occasionally in coarse bands or hyaline masses. In fibrinous effusions large masses of stringy fibrin may float in the exudate, while the serous surface may be covered with a thick layer of stringy fibrin, or in mild cases only small strings or flakes may be scattered over the surface. In the lung the alveolar spaces may be completely filled with a network of fine fibrin fibrillæ enclosing leucocytes, red blood cells, and desquamated epithelial cells in its meshes. In the kidneys fibrillar or hyaline fibrin may be found in the tubules. In the follicles of the spleen and lymph glands the spaces between the cells may be filled with a fibrinous exudate. The intercellular spaces in tubercules are also commonly filled with an exudate of fibrin. According to Neumann the fibrinous material found in certain inflammations of serous membranes is not an exudate, but the result of a "fibrinoid degeneration" of the superficial connective tissue of the membrane. This theory is not supported by the actual findings, and has not been generally accepted.

If the inflammatory exudate contains a large number of leucocytes, but not in a sufficient number to cover up the structure of the tissue, it is spoken of as a *small-celled infiltration*. When the leucocytes in the exudate are so numerous as to give it a white or creamy appearance it is called pus; such an exudate on mucous membranes is a *purulent catarrh;* in the body cavities a *purulent effusion* or *empyema*. Purulent vesicles are styled *pustules;* deep-seated purulent exudates, *abscesses*. Seropurulent exudates may infiltrate the tissues (purulent edema). Fibrin is a very frequent accompaniment of purulent exudates (fibrinopurulent exudate); and the inflammations of serous membranes usually produce exudates of this kind. Usually with an increase of pus formation the amount of fibrin decreases and the fibrin masses present in the exudate begin to dissolve. Fibrin coagula infiltrated with leucocytes become white and friable. The presence of large numbers of red blood cells (hemorrhagic exudate) and blood plates is found usually in association with fibrinous exudation, but they may also be present in serous inflammations.

The exciting causes of [illegible] those of inflammations in general. [illegible] fibrinous, and fibrinous [illegible] thermal and chemical [illegible] due to infection with the *Diplococcus Bacillus diphtheriæ*, and the [illegible] Purulent exudates may also be [illegible] action (aseptic pus), but are most frequently [illegible] of infection by the *Staphylococcus pyogenes* [illegible] cocci, gonococcus, etc. After the [illegible] produced them cease to operate [illegible] charged from the body, absorbed, organized, or under certain conditions encapsulated and calcified. Autolysis, digestion by proteolytic ferments and phagocytosis are important factors in the resorption of exudates. In the processes of repair and organization it is possible that the exudate may serve as a source of nutriment for the new-formed tissue cells.

The significance of pathological exudation is practically that of inflammation in general. The old view, and the one still accepted by some clinicians, is that they are essentially harmful. From the pathological side, however, inflammation must be regarded as a reaction on the part of the body to local injuries, having for its purpose protection and repair. Though both protective and reparative measures may be imperfectly carried out and even many times in themselves cause further damage, it must be granted that inflammation is essentially an attempt at self-preservation. In this attempt the constitutents of the exudate, both cellular and fluid, play the chief part. The leucocytes of the exudate act as phagocytes and as sources of bactericidal and antitoxic substances, or may even furnish nutriment to formative tissue. The fluids of the exudate likewise possess important germicidal and antitoxic powers; they serve further as diluting and irrigating agents; and may also carry nutriment to the newly forming cells. Even fibrinous exudates may serve a beneficial purpose in limiting the action of bacteria. Masses of leucocytes may also form mechanical barriers to the spread of germ growth.

In the exudate we therefore find the means of counteracting or destroying harmful agents, neutralizing their poisons, protecting the organism, and aiding in healing. But in the attempt to fulfil these functions exudates may in themselves create new conditions that may damage the body. The pressure upon the brain of meningeal exudates, the disturbance of respiration and heart's action by pleural and pericardial effusions, the closure of the glottis from inflammatory infiltration, etc., are examples of the imperfect adaptation of the process, which though in the main intended to be beneficial may often overreach its aim. (See also *Inflammation.*)

ALDRED SCOTT WARTHIN

Eye, Anatomy of the. GENERAL ARRANGEMENT.—The eyeball (see Fig. 2221) is a spheroidal expansion attached to the end of the optic nerve, optically equivalent to a camera obscura and filled with fluid or semifluid contents. It has three concentric envelopes or coats: an outer one, protective in character, formed of fibrous tissue, called the *sclera* behind, where it is white and opaque, and the *cornea* in front, where it is clear and transparent; a middle one, nutritive in character, composed of vascular tissue intermingled with pigment, called the *chorioid* behind, in front assisting to form the *ciliary body* and the *iris* or diaphragm which regulates the admission of light through a central aperture, the *pupil;* an inner one, percipient in character, formed of nervous elements, and called the *retina*.

The rays of light that pass through the pupil are focused dioptrically by the refractive action of a clear, lenticular body, the *crystalline lens*, which is set behind the iris and divides the cavity of the eyeball into two compartments or chambers: the *aqueous chamber*, situated in front and containing a

watery fluid called the *aqueous humor*, and the *vitreous chamber* behind, containing the semifluid *vitreous humor* or *body*. The aqueous chamber is subdivided by the iris; the space in front of that curtain being known as the *anterior chamber*, that between it and the lens as the *posterior chamber*.

In describing the eye terms applicable to a spheroid are used (see Figs. 2222 and 2223). The antero-posterior diameter is termed the *axis*, the ends of that diameter the *poles*. The *equator* is a line on the surface equidistant from these poles: circles and

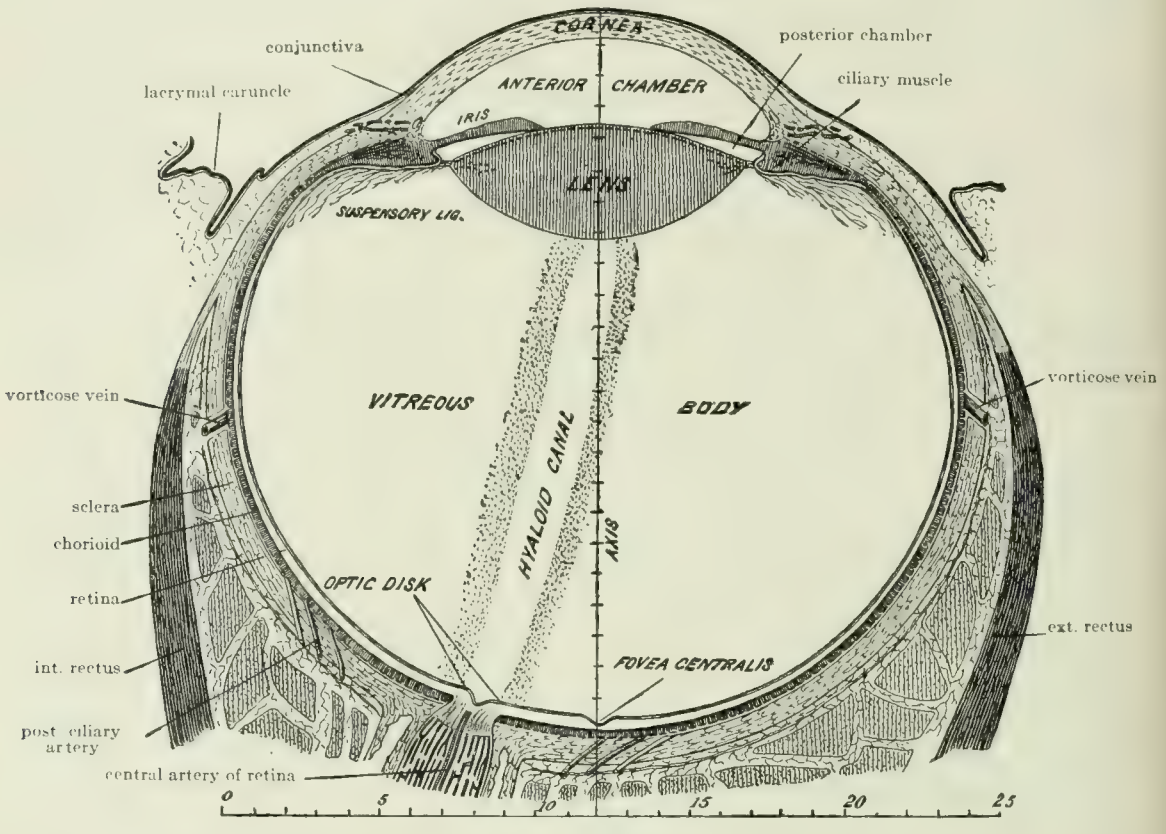


Fig. 2221.—Diagram of Horizontal Section of Eyeball Drawn to an Accurate Scale. (Flemming.)

directions parallel to it are termed *equatorial*. Circles drawn from pole to pole are termed *meridians*, directions along these are *meridional*. Any half of the ocular globe is called a *hemisphere*, any fourth a *quadrant*. The lateral aspects of the globe are distinguished as *temporal* and *nasal*.

The eyeball is not a perfect sphere. Its antero-posterior diameter averages 24.2 millimeters, its transverse diameter 23.6 millimeters, and its vertical diameter 23.2 millimeters. The radius of curvature of the cornea is considerably less than that of the sclera and a slight groove, the *scleral sulcus*, separates the two (see Fig. 2224). Individual variations may lead to visual defects. An examination of the annexed figures (Figs. 2225, 2226, and 2227) will show that a lengthening of the axis of the ball may cause the rays from distant objects to focus in front of the retina, while a shortening of that axis may focus them behind it. The average weight of the eyeball is about seven grams, its specific gravity about 1.022 to 1.030. At birth its weight as compared with the rest of the body is as 1 : 419; at maturity it is as 1 : 4,832.

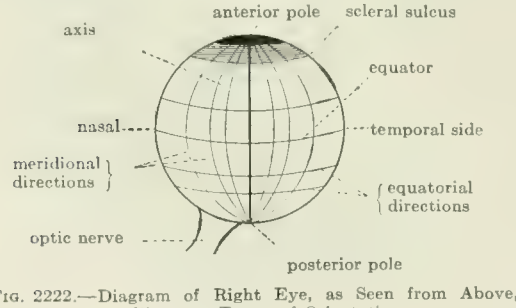


Fig. 2222.—Diagram of Right Eye, as Seen from Above, to Illustrate Terms of Orientation.

Relations.—The eye is placed just within the margin of the pyramidal cavity of the orbit, 16 to 18

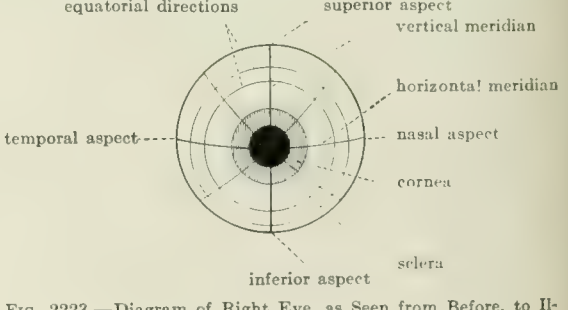


Fig. 2223.—Diagram of Right Eye, as Seen from Before, to Illustrate Terms of Orientation.

millimeters from the optic foramen (Figs. 2228 and 2229), usually a little nearer to the upper margin and to the temporal side, though equidistant from the upper and lower walls at the equator (Fig. 2230). Its axis makes an angle of about twenty degrees with the axis of the optic nerve. It fills about one-fifth of the cavity, the remainder being occupied by the ocular vessels, nerves and muscles, the lacrymal gland and the bulbar fascia, loose orbital fat lying in the interstices. The edge of the orbit retreats somewhat on the temporal side so that the eyeball is there somewhat more accessible for operation. The distance of the two eyes from each other varies from 55 to 61 millimeters.

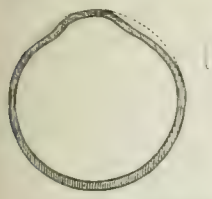


Fig. 2224.—The Eyeball Compared with a Sphere.

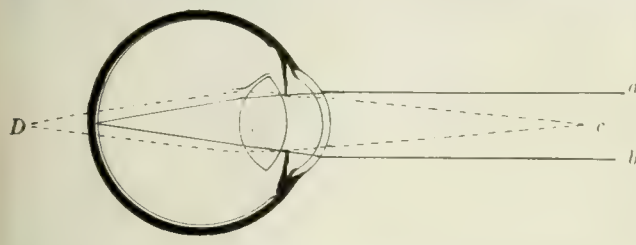


Fig. 2225.—An Emmetropic or Normal Eye. Parallel rays, *a b*, are focused upon the retina; while divergent rays, as those proceeding from the point *c*, come to a focus *behind* the retina, as at *D*.

In front the eye is protected by two movable folds of integument, the eyelids, or *palpebræ*, which, when open (Fig. 2231) form an aperture known as the *rima palpebrarum* or palpebral opening that exposes nearly the whole of the cornea and a considerable portion of the sclera. About 30 millimeters in length and 12 to 15 millimeters high, it is curved above and below, uniting internally and externally at the *angles* or *canthi* of the eye. The external angle is sharp, the internal rounded, forming a slight recess known as the *lacrymal bay* (*lacus lacrimalis*). It is here that are found passages for the removal of lacrymal fluid (Fig. 2232). Two small openings, the *puncta lacrimalia*, lead into the short lacrymal ducts which discharge through the nasal duct into the inferior meatus of the nose. With horizontally directed vision the upper lid impinges slightly upon the cornea, the lower falls near its inferior edge; when looking upward a strip of sclera is visible below. The axis of the palpebral opening is slightly higher at the outer angle, but when the eyes are closed (Fig. 2233) the outer angle descends.

The lids are lined by a thin epithelial membrane, the *conjunctiva*, which extends from them over the anterior surface of the ball (Fig. 2234). The place of reflection [illegible] *fornix* of the conjunctiva and is [illegible]

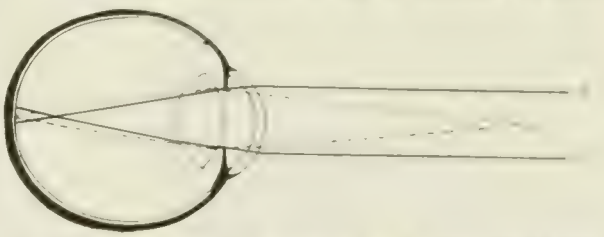


Fig. 2226.—A Myopic or Short-sighted Eye. Parallel rays [illegible] verge before reaching the retina. Rays must be [illegible] focus there.

meters from the upper lid, 9 millimeters from the lower one when the eyes are open. Its distance from the cornea is 10 millimeters above, 8 millimeters below, 14 millimeters at the outer angle, and 7 millimeters at the inner angle (Testut).

Within the orbit a thin aponeurotic sheet, the *bulbar fascia* or capsule of Tenon, separates the eyeball from the orbital fat (Fig. 2235). This invests the posterior part of the ball with two layers, one closely adherent to the sclera and sometimes called the *episclera*, the other reflected over the orbital contents. The two layers are united by fine trabeculæ, and there is between them a loose lacunar interval, the *periscleral space*, that communicates with the

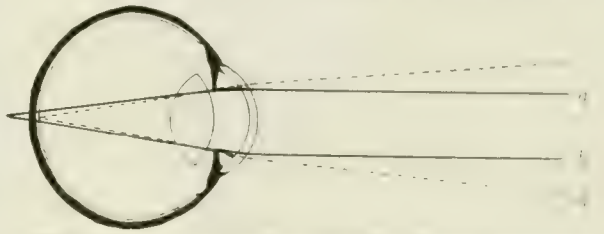


Fig. 2227.—A Hypermetropic or Far-sighted Eye. Parallel rays [illegible] *behind* the retina. Rays must be [illegible]

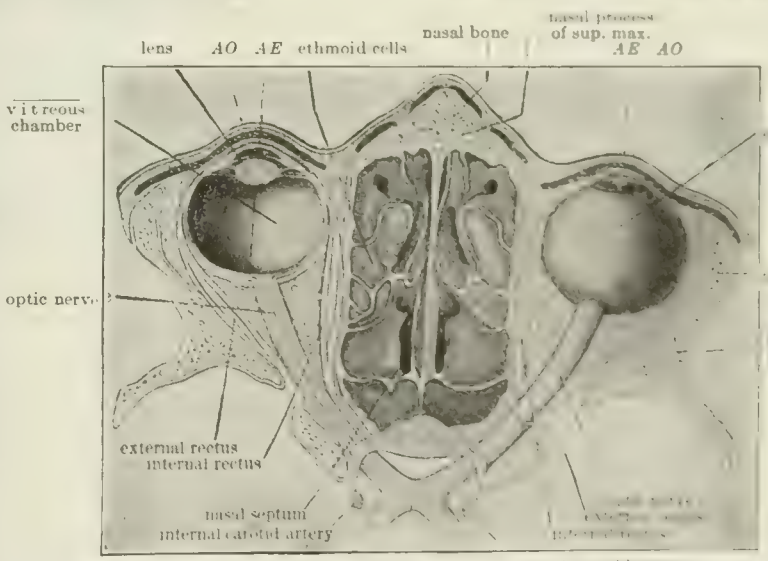


Fig. 2228.—The Eyes and Optic Nerves Seen from Above after Removal of the Roof of the Orbits. *AO*, Axis of orbit; *AE*, axis of eye.

perineural space of the optic nerve. Processes from the bulbar fascia invest the structures that pass to the eyeball. Those that extend upon the ocular muscles are of considerable surgical importance. Extensions also pass to the fornices of the conjunctiva, to the eyelids, and to the edges of the orbit. As the latter assist to retain the contents of that cavity, they are collectively known as the *orbital septum*.

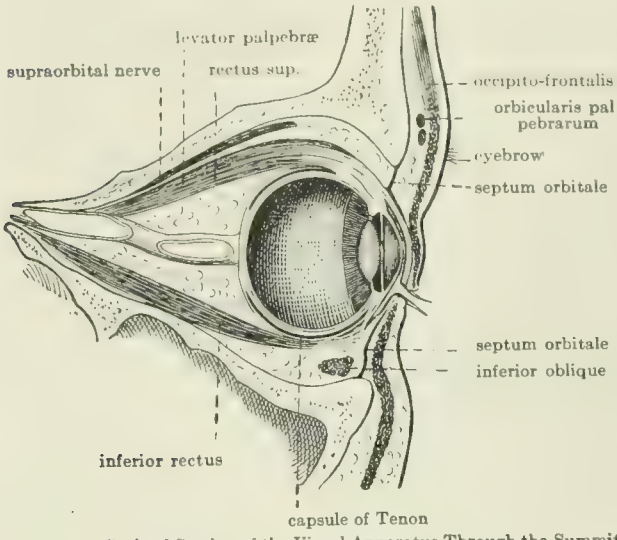


Fig. 2229.—Sagittal Section of the Visual Apparatus Through the Summit of the Cornea and the Optic Foramen. (Merkel.)

Development.—The percipient portion of the eye is, like the essential part of other organs of sense, derived, either directly or indirectly, from the ectoderm. In its simplest form, as seen in invertebrates, it consists merely of tegumentary cells, forming eye spots or retinas, surrounded by pigment and communicating by filamentous processes with nervous ganglia. Often, by a thickening of the epidermis, one or more lenses are developed in connection with these.

In vertebrates the ectodermal integument becomes infolded to form the central nervous system, and the development of the eye is more complicated. In Amphioxus there appears, toward the close of the embryonic period, on the swollen anterior end of the simple tube that forms its central nervous system, a pigmented spot that is believed to represent an eye. To this spot rays of light pass through the pellucid jelly that covers the animal externally, and, arrested by the pigment, excite directly the cells of the neural tube and apparently impart an obscure sensation of vision. In this primitive form, therefore, vision appears to be a direct function of a specialized portion of the central nervous system.

An examination of the visual organs of higher vertebrates, including man, shows that here too the essential element was primitively a portion of the central nervous system which, extending peripherally, became separated and associated with other elements to form a complicated apparatus. The retina may be regarded as a specialized portion of the cortex of the brain, the optic nerve as a fiber tract, the lens as an epithelial invagination, the cornea, sclera, chorioid, and contents of the eyeball as connective-tissue derivatives.

In the human embryo of three weeks (corresponding to the chick of two or three days) the central nervous system is also tubular, being formed by the approximation and gradual concrescence of the edges of a groove. The area that is to form the retina lies at first along the outer edges of the groove, in the region known as the neural crest, from which also originate the cells for the sensory nerves. The retinal cells differ from the latter in that, as the edges of the groove fold over to form the tube, they are gradually drawn in until they lie along the sides of the cavity (Fig. 2236, A, B, C, D).

This peculiar displacement of the cells of the retinal area is made possible by delay in the concrescence of the edges of the groove. If this occurs prematurely the fetus develops but a single orbital cavity, a teratological phenomenon known as *cyclopia*, which differs according to the stage at which union takes place. If early, the two retinas may be fused together to form a single eye; somewhat later, the two are imperfectly united; still later, two eyes exist in a single median orbit.

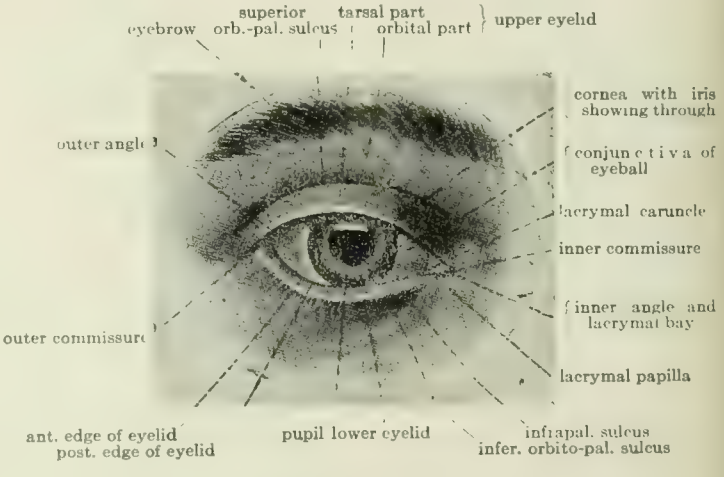


Fig. 2231.—The Eye as Seen with Lids Open. (Toldt.)

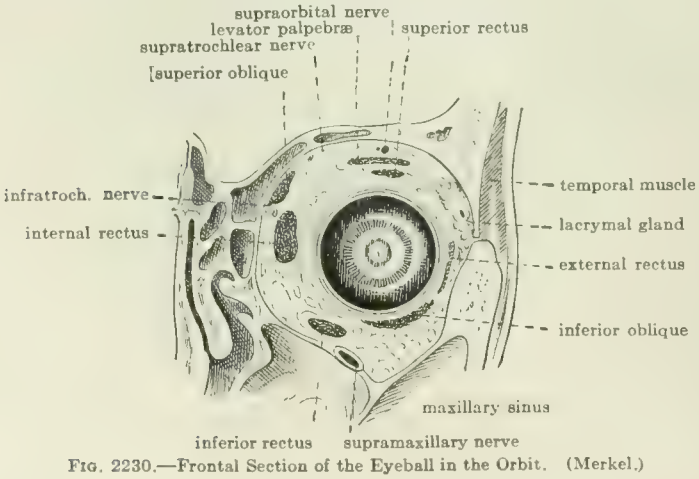


Fig. 2230.—Frontal Section of the Eyeball in the Orbit. (Merkel.)

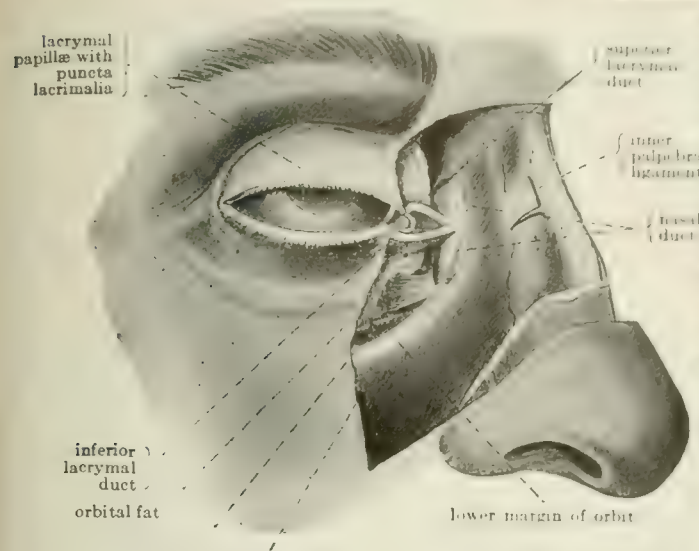


Fig. 2232.—The Lacrymal Passages.

At the period we are considering the neural tube shows at its cephalic end three bulbar enlargements, the primary cerebral vesicles. It is from the anterior of these, the forebrain, that are formed the parts immediately concerned with vision: the retinal areas, the optic nerves and tracts, the corpora geniculata, and the optic thalami. The forebrain now widens out laterally, forming two hollow protrusions, whose bulbar extremities, containing the retinal areas, are called the primary ocular

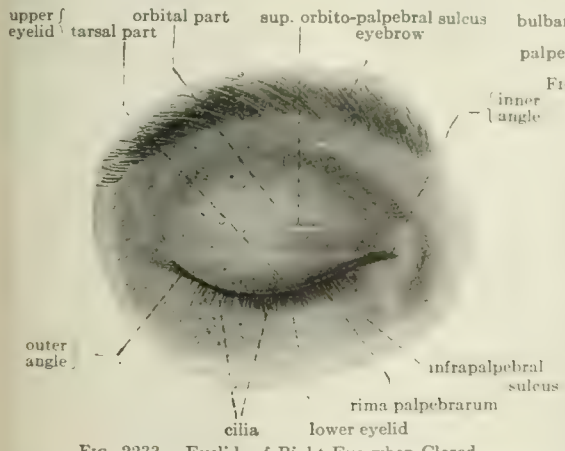


Fig. 2233.—Eyelids of Right Eye when Closed.

vesicles, the constricted pedicles, from which the optic nerves are formed, being known as the optic stalks. The cavity of each still communicates freely with that of the forebrain (Figs. 2237, 2238).

The ocular vesicles in their outward growth soon reach the epithelium or ectoderm of the side of the head which, at the place of contact, becomes thickened and cupped. This cupping or invagination continues until another vesicular structure is formed, the lenticular vesicle, from which develops the crystalline lens. The intrusion of the lens upon the growing end of the ocular vesicle causes the latter to assume a shape like that of a thick-walled cup with a marble somewhat smaller compressed against its surface. Because of this change of shape it is henceforth called the optic cup. The process diagrammatically in Figs. 2240 to 2244. The edge of the cup is the future margin of the pupil; its walls are double, the inner retinal layer being much thicker than the outer one in which pigment is deposited; they are at this stage detached but active growth is less rapid and a fissure is thus formed, known as the choroidal cleft, through which wandering mesenchymal cells penetrate between the retina and the lens to form the vitreous body. The interval between the layers is soon obliterated. The central artery of the retina enters the cleft back of the cup, upon the optic stalk, thus becoming finally enclosed within the

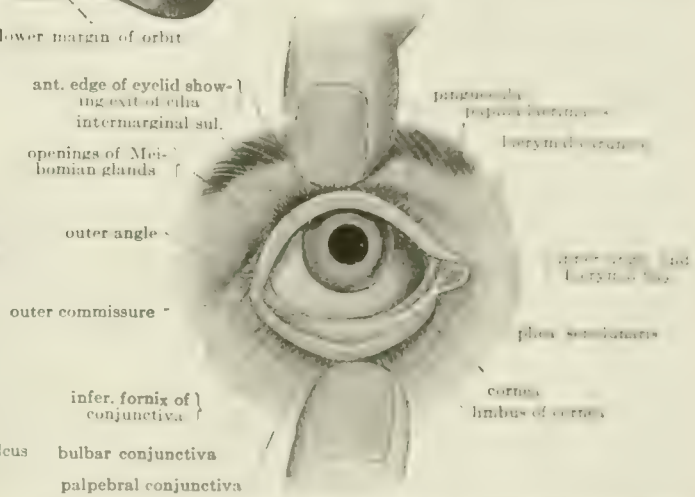


Fig. 2234.—Widely Opened Eye of an Elderly Person. Lower Lid Everted.

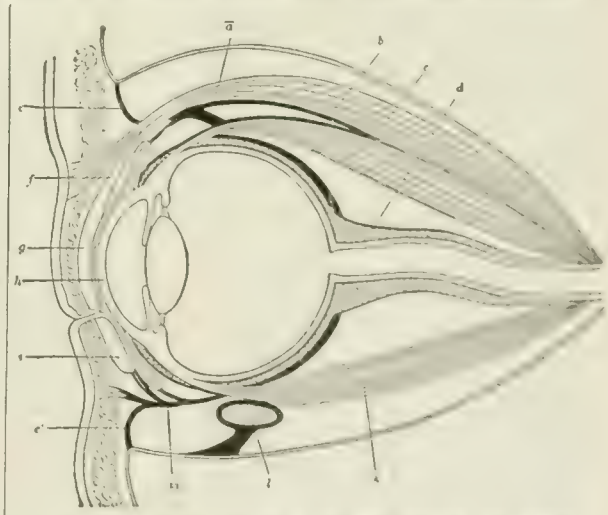


Fig. 2235.—Sagittal Section of the Eye and the Orbital Fascia and its Attachments. *a*, Periosteum of orbital roof; *b*, levator palpebræ; *c*, rectus superior; *d*, septum orbitale; *e*, tendon of [illegible]; *f*, tendon of [illegible]; *g*, cornea; *h*, tarsus inferior; *k*, inferior rectus muscle; *l*, inferior oblique muscle; *m*, prolongation of bulbar fascia.

optic nerve. The cleft closes early but a trace of it may often be found in the adult. If the closure is incomplete the ocular defect known as coloboma occurs, causing distortion of the pupil or a defect of the visual field.

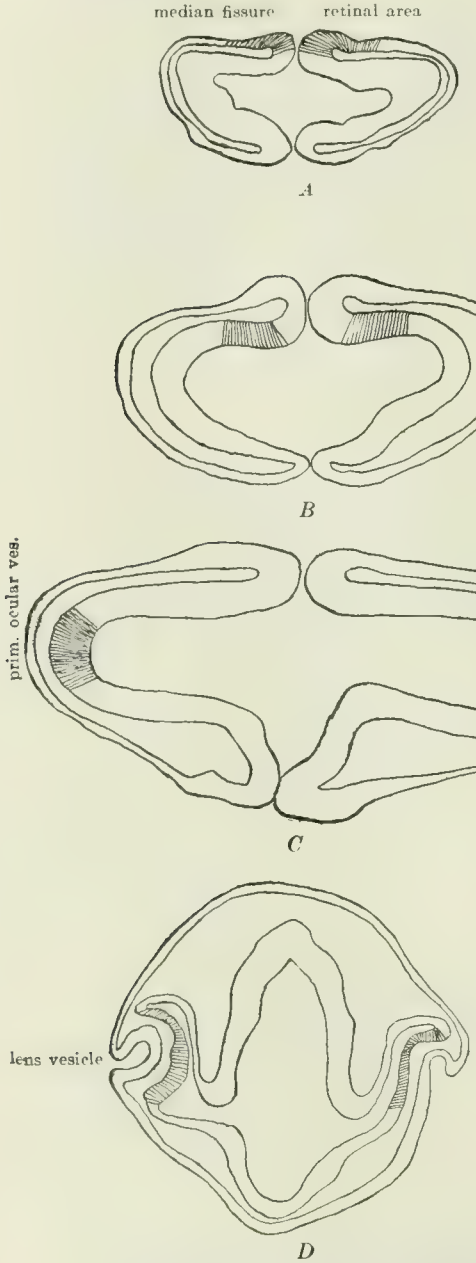


Fig. 2236.—Diagrams showing the Displacement of the Retinal Cells and their Relation to the First Cerebral Vesicle. (Dejerine.) *A* and *B* show the early development of the first primitive cerebral vesicle; *C*, the primitive ocular vesicle; D, the secondary ocular vesicle and the lens vesicle.

The retina develops like a part of the cerebrospinal axis. Spongioblasts and neuroblasts arise in it, the former developing into the supporting tissue of the retina or fibers of Müller of which the expanded bases form the internal limiting membrane, the distal arborescent extremities the external limiting membrane in which spaces are left which eventually are occupied by the rods and cones. The neuroblasts appear first in the area centralis, afterward extending peripherally as far as the ora serrata. Beyond this, in the retinal layer of the ciliary region and the iris, spongioblasts alone occur. The neuroblasts develop axis-cylinder processes that grow inward along the optic stalk, gradually obliterating its cavity and constituting the optic nerve. The percipient elements (rods and cones) are the last to develop, not appearing until the fifth month in man and after birth in kittens and rabbits.

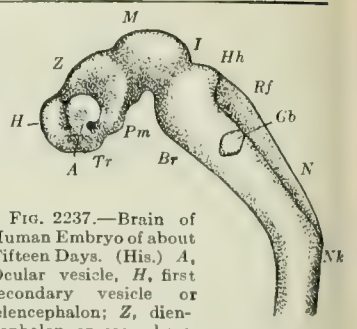


Fig. 2237.—Brain of Human Embryo of about Fifteen Days. (His.) *A*, Ocular vesicle, *H*, first secondary vesicle or telencephalon; *Z*, diencephalon or second secondary vesicle; *M*, midbrain; *I*, isthmus between mid- and hindbrain; *Hh*, fourth secondary vesicle; *N*, fifth secondary vesicle; *Gb*, otic vesicle; *Rf*, fourth ventricle; *Nk*, neck curvature; *Br*, pons curvature; *Pm*, mammillary process; *Tr*, infundibulum.

In its early stages the lenticular vesicle is proportionately larger than at birth, filling the cavity of the optic cup so that there is but little space left between it and the retina. Its cells are soon arranged in a single layer, those on its outer aspect remaining cubical and forming the so-called lens epithelium, while those on

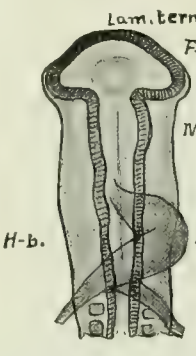


Fig. 2238.—Dorsal View of Head of Chick of Fifty-eight Hours. (Mihalkovics.) *Lam. term.*, Lamina terminalis; *F.b.*, forebrain; *Opt. v.*, ocular vesicle; *M.b.*, midbrain; *H*, heart.

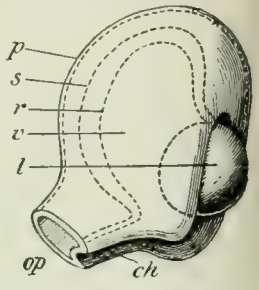


Fig. 2239.—Model showing Reconstruction of the Optic Cup. (Hertwig.) *p*, Outer wall of cup, which becomes the pigmented layer of the retina; *r*, its inner wall, which becomes the retina; *s*, temporary space between the two walls; *v*, vitreous chamber; *l*, lens; *ch*, chorioid fissure; *op*, hollow stalk of cup which becomes the optic nerve.

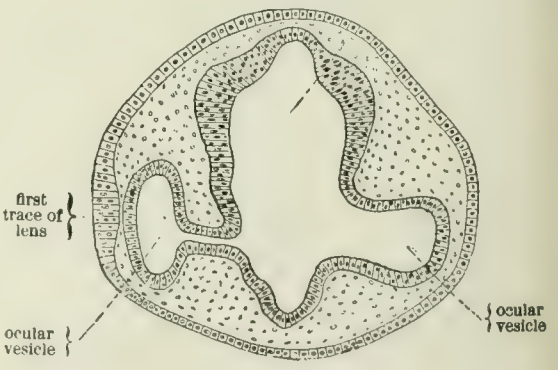


Fig. 2240.—Section of Head of Chick, Second Day of Incubation. (Duval.)

the inner or retinal aspect become greatly lengthened and form the lens fibers (Fig. 2245). By this process the cavity of the vesicle is finally obliterated. At the

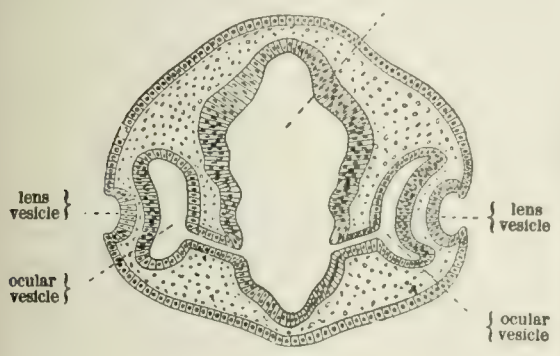


Fig. 2241.—Section of Head of Chick, Third Day of Incubation. (Duval.)

equator or edge of the lens there is a transition region where proliferation is most active. The lens increases in size by the addition of successive layers of fibers which extend from the anterior to the posterior surface. The structureless capsule of the lens is now believed to be a product of the cells themselves and not of mesoblastic origin.

Besides the capsule proper the lens is invested during fetal life by a vascular membrane, the *tunica vasculosa lentis*. The vessels that supply this are derived from the hyaloid artery, a branch of the central artery of the retina, and from the long and short ciliary arteries that supply the iris (Fig. 2246). The supply is especially great around the equator of the lens where proliferation is active. The portion of this membrane that lies in front of the lens stretches over the pupil or mouth of the optic cup, and is known as the pupillary membrane. The tunica vasculosa begins to disappear about the seventh month, but vestiges often remain after birth.

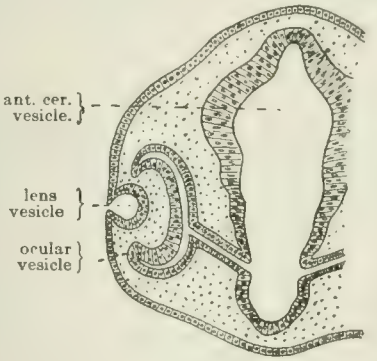


Fig. 2242.—Further Development of Retina and Lens. The lens vesicle is still attached to the epidermis. (Duval.)

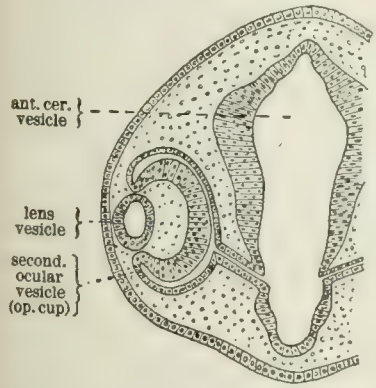


Fig. 2243.—Further Development of Retina and Lens. The lens vesicle has become entirely detached and lies at the entrance to the optic cup. The inner layer to the optic cup has begun to thicken.

Around the optic cup and the lens the mesoderm forms a complete investment in which two layers may be distinguished: an inner, more vascular one, which becomes the choroid coat, the ciliary body, the choroidal part of the iris and the pupillary membrane; and an outer, less vascular one,

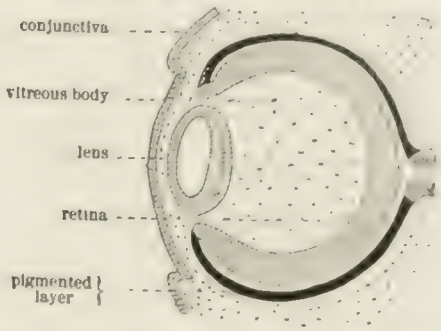


Fig. 2244.—Further Development of the Retina and Lens. The posterior wall of the lens has begun to thicken, the external layer of the optic cup is charged with pigment. (Duval.)

which forms the sclera and cornea. In front of the lens a cleft appears which enlarges to become the aqueous chamber (Fig. 2247).

The eyes have first a lateral position like those of fishes, but the growth of the superior maxillary and nasal processes causes them to assume their adult situation. At first the cornea is entirely uncovered, the lids develop as folds of integument.

The nasolacrymal duct is formed in the fold between the superior maxillary and nasal processes by the canalization of a cord of infolded ectodermic cells.

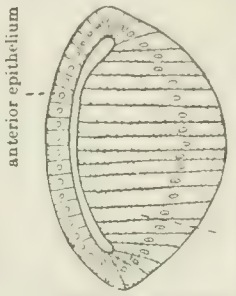


Fig. 2245.—Final Stages of Development of Lens. The cavity of the lens vesicle almost wholly disappears. (Duval.)

The Outer or Fibrous Coat.—Analogous to the dura mater of the brain with which it is continuous through the dural sheath of the optic nerve, this tunic completely invests the eyeball except where penetrated by vessels and nerves. It is composed of fibrous tissue irregularly arranged behind, producing the white, opaque sclera, more regularly in front, forming the clear, transparent cornea. It is very scantily supplied with vessels and nerves, but has numerous lymph channels that appear to afford it nutrition. Associated with these and lying in the interstices of the tissue are various specific forms of corpuscles. The density and hardness of the coat efficiently protect the eye and

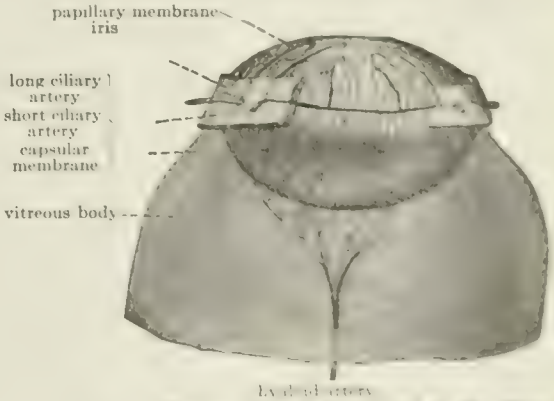


Fig. 2246.—The Vascular Tunic of the Lens in the Fetus. (Kollmann.)

contribute to its shape, which essentially depends, however, upon the tension produced by the enclosed contents.

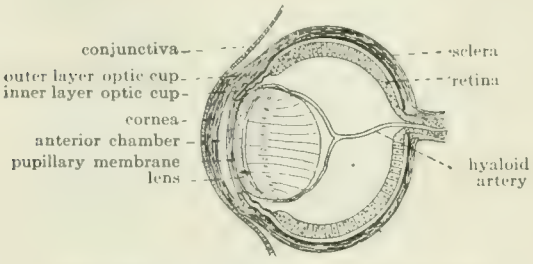


Fig. 2247.—Formation of the Anterior Chamber.

The Sclera.—Four-fifths of the surface of the eyeball is formed by the dense, opaque structure known as the "white of the eye." Its dead white appearance is due to the interference of light occasioned by the irregularly interwoven bundles of its fibers. In children and the darker races the underlying pigment shows through it slightly, giving it a bluish cast. In old persons it is yellowish from the deposit of fat within it.

Two principal openings occur in the sclera: one in front, where the transparent cornea is set into it like the crystals of a watch into its frame, the fibers of the two mutually interblending; one behind, where the optic nerve enters at the so-called *optic canal* (porus opticus). Strictly speaking, the sclera is not wholly deficient in the latter situation, as it is represented by a perforated sheet of connective tissue, the *lamina cribrosa*, through which the fibers of the optic nerve pass. The canal is situated about three millimeters from the posterior pole on the nasal side and one millimeter below the horizontal meridian. Since the fibers of the optic nerve lose their medullary sheaths as they pass forward, the canal contracts funnel-wise, from without inward, terminating within in a crest-like ridge, the *pecten sclerœ*. Other perforations for vessels and nerves occur, viz., a posterior ciliary set, arranged about the optic nerve (Fig. 2248), together with those for the long ciliary vessels and nerves lying a short distance farther forward; a middle set, comprising the vorticose veins; and an anterior ciliary set a short distance behind the corneoscleral junction.

The sclera attains its maximum thickness of about one millimeter in the vicinity of the optic nerve entrance where it is required to support the most sensitive part of the retina. It grows gradually thinner forward until, just behind the insertion of the recti muscles, it is but 0.35 millimeter thick. The tendons of those muscles reinforce it to some extent and at the corneoscleral junction it measures 0.60 millimeter.

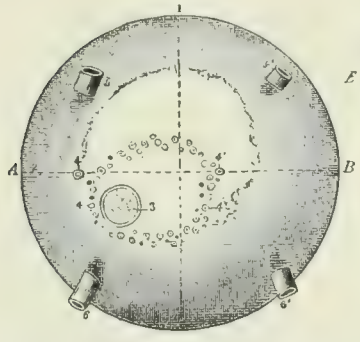


Fig. 2248.—Posterior View of Right Eye, showing Entrance of Optic Nerve. (Testut.) *A*, Nasal side; *B*, temporal side; 1, vertical meridian; 2, horizontal meridian; 3, optic nerve; 4, 4, ciliary vessels and nerves; 4′ 4′, long ciliary arteries; 5, 5′, superior vorticose veins; 6, 6′, inferior vorticose veins.

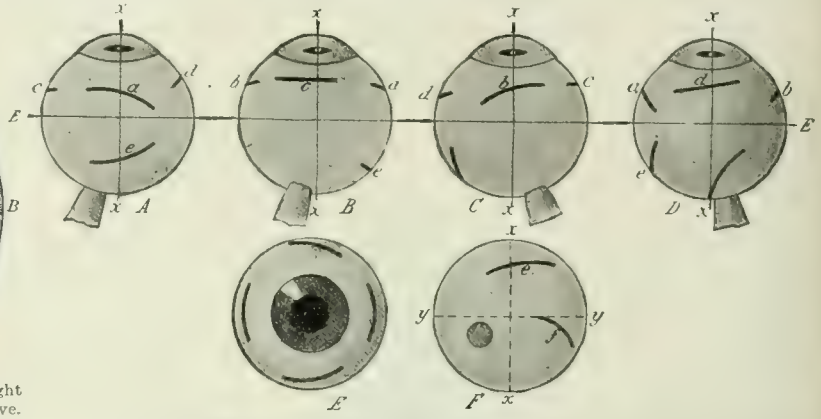


Fig. 2249.—Insertion of the Ocular Muscles upon the Sclera of the Right Eye. Drawn from the determinations of Fuchs. *A*, View from above; *B*, from nasal side; *C*, from below; *D*, from temporal side; *E*, from the front; *F*, from behind; *a*, rectus superior; *b*, rectus inferior; *c*, rectus medialis; *d*, rectus lateralis; *e*, obliquus superior; *f*, obliquus inferior; *E E*, equator; *xx*, axis. In *F*, *y y*, horizontal meridian; *xx*, vertical meridian.

The recti muscles are inserted by means of flattened expansions that blend intimately with the sclera. The adjoining sketch (Fig. 2249) shows that their insertions follow a spiral line running at a distance of five milli-

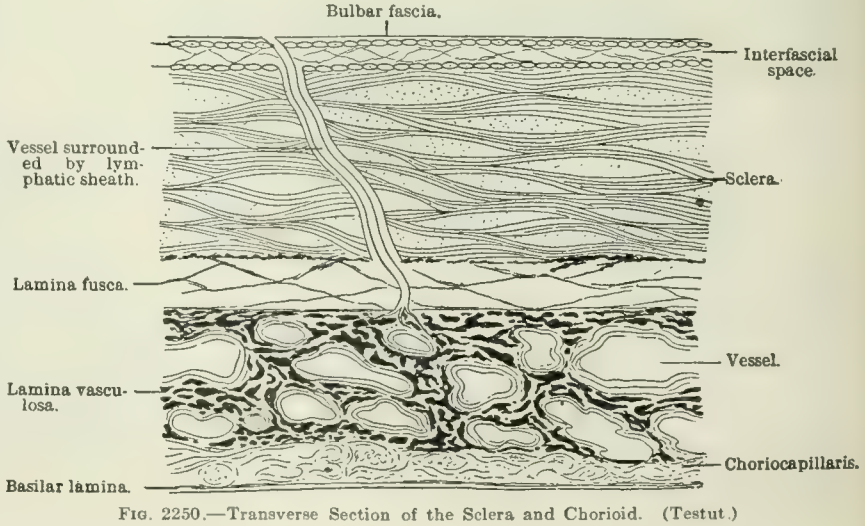


Fig. 2250.—Transverse Section of the Sclera and Chorioid. (Testut.)

meters from the corneal margin for the rectus medialis to eight millimeters for the rectus superior. The oblique muscles are inserted in the posterior hemisphere, their lines of insertion being diagonal to the meridians. The striated fibers of the inferior oblique are inserted directly upon the sclera without the intervention of a tendon.

The density of the sclera is considerable, its weight being at least one-sixth that of the entire eye.

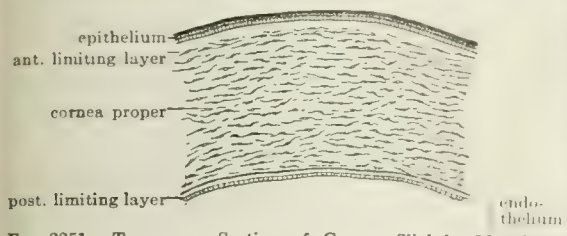


FIG. 2251.—Transverse Section of Cornea Slightly Magnified. (Gerlach.)

The sclera is a typical connective-tissue structure, being composed of white fibrous tissue with a few yellow elastic fibers intermingled (Fig. 2250). On boiling it yields gelatin. The bundles are in all parts of it irregularly arranged, though equatorial bands are more common near the corneoscleral junction. The interstitial spaces are small and cleft-like. In their walls are found fixed cells, the scleral corpuscles, in their cavities wandering leucocytes. Pigmented

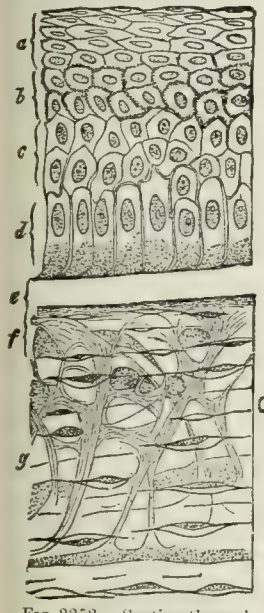


FIG. 2252.—Section through the Anterior Portion of the Cornea of the Calf. (Waldeyer.) *a*, Flattened epithelial cells; *b*, prickle cells; *c*, polymorphous cells; *d*, basal layer of club-shaped cells; *e*, anterior elastic lamina; *f* and *g*, substantia propria of cornea.

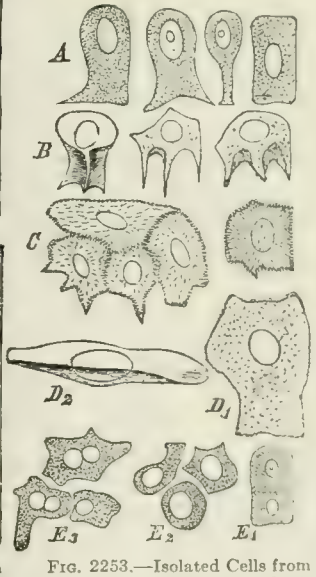


FIG. 2253.—Isolated Cells from the Corneal Conjunctiva. (Waldeyer.) *A*, From the basal layer; *B*, polymorphous cells; *C*, prickle cells; *D*, flattened cells; D_1, plane view; D_2, side view; *E*, young cells from the middle layers; E_1, cell undergoing division; E_2, cells with one nucleus; E_3, multinucleate cells.

connective-tissue cells occur, especially in the deeper layers, where their aggregation gives a dark-brown color to the tissue, called for this reason the *lamina fusca*. Perivascular and perineural lymph channels extend from the periscleral space into the tissue along the interpenetrating vessels and nerves and communicate with a lymph space, the *perichorioidal space*, that occurs between the [illegible] It is mostly by the lymphatic [illegible] sclera is nourished, as its blood-[illegible]

Near the corneoscleral junction there occurs an equatorially extending channel, called the *scleral sinus* or canal of Schlemm, that is now considered to be of a venous character. It is probable by this avenue that the aqueous humor is removed from the

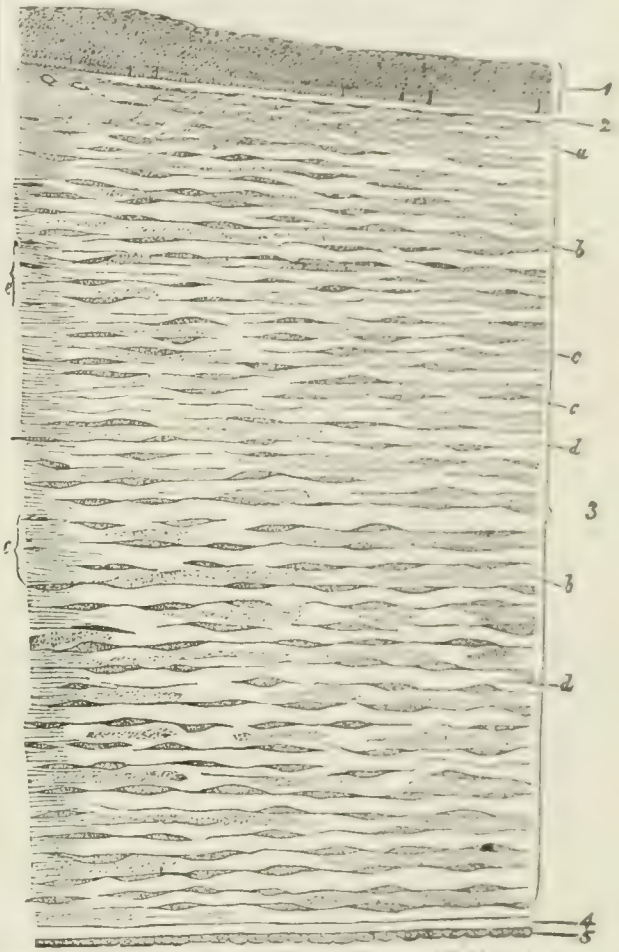


FIG. 2254. Section through Human Cornea. [illegible] Conjunctival epithelium; 2, [illegible] propria; 4, posterior elastic lamina; 5, [illegible] from anterior elastic lamina entering [illegible] fibers cut transversely and [illegible] fasciculi cut lengthwise and therefore appearing [illegible] *c*, *c*, corneoscleral junction.

eye and the proper interchange of fluids effected. It appears to have no direct communication with the chambers, and the action of removal must be by intercellular transudation (Leber).

The nerves supplying the sclera are few in number and are derived from the ciliary nerves.

The Cornea.—This is also a connective-tissue structure formed of superposed and anastomosing lamellæ, closely applied to each other and with no substance intervening that can vary the refractive force of its fibers. Although composed of many different units—epithelium, limiting membranes, successive layers of connective tissue, lymph channels, corpuscles, and nerves—all have the same index of refraction and the membrane is perfectly transparent. A slight disturbance tending to derange its [illegible] justment, such as compression or other strains, the

absorption of fluids, etc., at once beclouds it. After death it gradually becomes opaque, partly because

Fig. 2255.—Section of Human Cornea Stained with Chloride of Gold, showing the Corneal Corpuscles and Nerve Endings. (Waldeyer.)

of degeneration of its epithelium, partly because it absorbs the aqueous humor.

The history of its development shows that its layers may be classified according to their sources: (1) *conjunctival,* forming the exterior layer of epithelium, derived from the ectoderm; (2) *scleral,* forming the main portion of the structure together with its anterior elastic lamina, derived like the sclera from the mesoderm (mesenchyme); (3) *chorioidal,* forming the endothelium lining the anterior chamber together with the posterior elastic lamina, also of ectodermic origin but correlated with the middle tunic of the eye.

Set like a window in the frame of the sclera its outline is slightly elliptical, its horizontal diameter being 11.6 millimeters, while its vertical one is but 11 millimeters. The outer and inner surfaces are unequally curved, the inner one having nearly the curvature of a sphere with a radius of 6 millimeters, while the outer one has that of an ellipsoid with a horizontal radius of 7.8 millimeters, and a vertical one of 7.7 millimeters, even greater variations being frequently observed. The surfaces therefore are not parallel, and the thickness of the cornea varies from 1.1 millimeters at its periphery to 0.9 at the ocular axis. It attains its permanent dimensions early; its weight averages 180 milligrams, one-fortieth that of the entire eye; and its specific gravity is 1.076 (Davy). Its index of refraction is 1.3523, that of distilled water being 1.3358 (Krause). When boiled it yields a form of chondrin instead of gelatin as does the sclera. Its percentage of water is 72.75.

The main substance of the cornea is a lamellated connective tissue lined both without and within by clear structureless elastic laminæ, then clothed without by the epithelium of the conjunctiva, within by the endothelium of the anterior chamber. Thus there are five varieties of tissue to be considered (Fig. 2251).

The corneal conjunctiva is an epithelium corresponding with that of the general surface of the body, but having fewer layers of cells and no corneous layer. The deeper cells are expanded at the base and show signs of mitotic division (see Figs. 2252, 2253). Those of the middle layer ("prickle cells") are surrounded by intercellular passages that permit the circulation of lymph.

The anterior elastic lamina (Bowman's membrane, anterior limiting membrane) is a clear anhistous sheet that lines the cornea under the conjunctiva up to near the margin, sending down into the deeper layers fibers of a similar character. It behaves with reagents like the spiral fibers that encircle connective-tissue bundles, not dilating when treated with acetic acid, and resembles the subepithelial basement layer of many membranes.

The proper tissue of the cornea presents from sixty to sixty-five lamellæ (Fig. 2254) composed of flattened bundles of white fibrous tissue arranged nearly at right angles to each other. Between these is an intricate system of interfascicular spaces or lymph

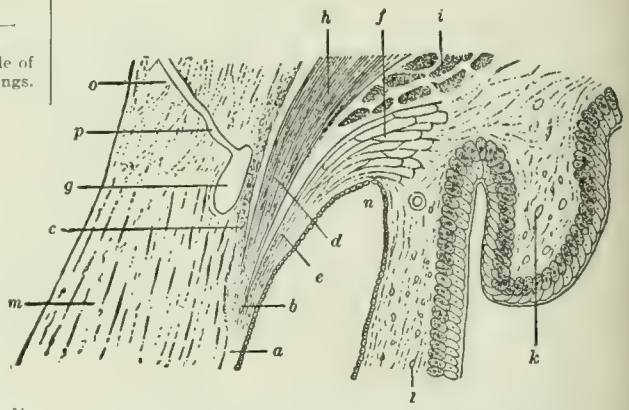


Fig. 2256.—Meridional Section Showing the Connection Between the Cornea and the Middle Coat of the Eye. (Testut.) *a*, Posterior elastic lamina; *b*, annular ligament; *c*, scleral fibers; *d*, ciliary fibers; *e*, posterior fibers forming the pectinate ligament; *f*, spaces of the angle of the iris; *g*, scleral sinus; *h*, meridional fibers of the ciliary muscle; *i*, annular fibers of same; *k*, ciliary process; *l*, iris; *m*, cornea; *n*, angle of the iris; *o*, sclera; *p*, scleral vein.

lacunæ connected with each other by fine canals and containing fixed cells, the corneal corpuscles (Fig. 2255). These have a resemblance to the osteoblasts

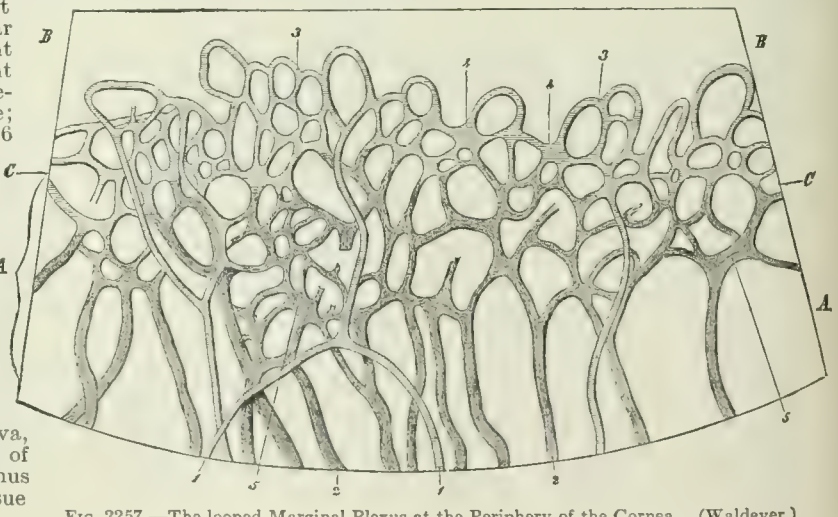


Fig. 2257.—The looped Marginal Plexus at the Periphery of the Cornea. (Waldeyer.)

of bone in that they occupy interstitial spaces and apparently send fine branching processes along delicate canals that communicate with other spaces. Wandering cells are also found in the passages of the cornea. At the corneal margin these passages communicate with similar ones in the sclera.

The posterior elastic lamina (membrane of Descemet, of Demours, of Duddell, posterior limiting membrane) is also an anhistous layer but apparently quite different in character and origin from the

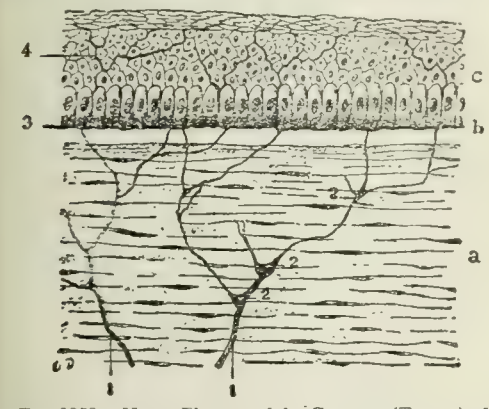


Fig. 2258.—Nerve Plexuses of the Cornea. (Testut.) 1, 1, Two afferent nerve trunks; 2, deep stroma plexus; 3, subepithelial plexus; 4, intraepithelial plexus; *a*, cornea proper; *b*, anterior elastic lamina; *c*, anterior epithelium.

anterior elastic lamina. It appears to act as a central tendon for the ciliary muscle. Its increase with age, and certain irregularities found on its surface lead to the conclusion that it is produced by the endothelial cells which it supports. At the margin of the cornea it becomes thickened into a ring-like zone, the *annular ligament*, beyond which it can be traced over to the insertion of the iris, as a series of distinct bundles of fibers, the *pectinate ligament*, separated by minute clefts, the *spaces of the angle of the iris* (Fig. 2256).

The endothelium that forms the posterior boundary of the cornea is a flattened single layer of cells similar

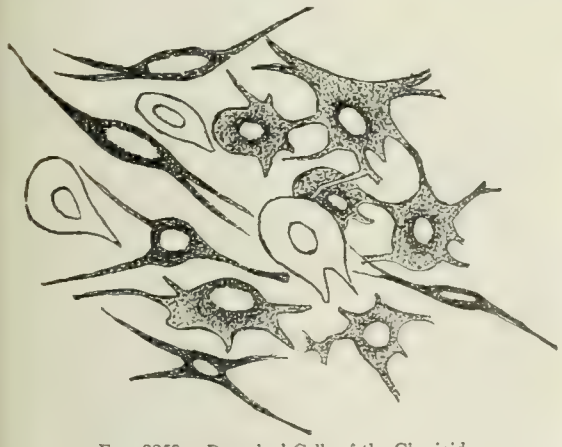


Fig. 2259.—Branched Cells of the Chorioid.

to those usually lining serous cavities. It is continuous over the acute peripheral portion of the anterior chamber (known as the *angle of the iris*) with the endothelium lining the anterior surface of the iris.

In the healthy cornea there are no blood-vessels, except just at the margin where vessels from the sclera form a looped network (Fig. 2257). Notwithstanding this, wounds of the cornea heal rapidly, [illegible] afforded by the copious supply of lymph.

The nerves that supply the cornea are derived from the anterior ciliary set which form, near the corneo-scleral junction, a close-meshed plexus, [illegible]

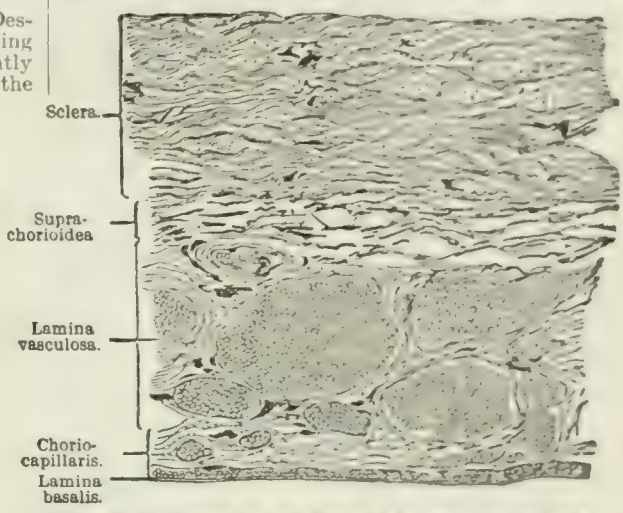


Fig. 2260.—Section of the Human Choroid. [Behm and Davidoff.]

annularis, from which sixty to eighty nerves, containing both medullated and non-medullated fibers, pass to the cornea, two-thirds going toward the anterior surface. They soon lose their medullary sheaths and form a second plexus, the *deep stroma plexus* (primary plexus, fundamental plexus) (Fig. 2258). Reaching the anterior elastic lamina, perforating fibers from this plexus penetrate that layer and unite to form a third or *subepithelial plexus* from which again fibers pass between the epithelial cells, forming a fourth, or *intraepithelial plexus*. From this as well as from the subepithelial plexus terminal filaments are given off on which are formed end organs shaped like rounded bulbs, hooks, loops, and platelets. So rich is this supply that it appears probable that every epithelial cell is in actual contact with a nerve fiber or its terminal.

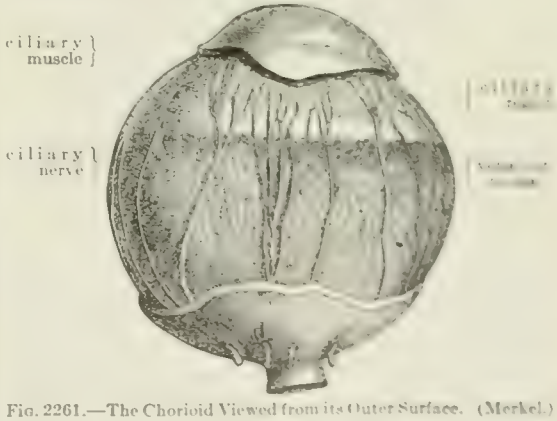


Fig. 2261.—The Chorioid Viewed from its Outer Surface. (Merkel.)

The Middle or Vascular Coat.—Considered from an embryological point of view this coat is properly divided into four regions: (1) The chorioid proper, comprising the pigmented vascular membrane that extends from the optic nerve entrance as far as the boundaries of the visual retina, which is limited by a crenulate line called the *ora serrata;* (2) the ciliary

chorioid, or ciliary body, a thickened portion containing muscular fibers and vascular plexuses; (3) the chorioidal part of the iris, comprising the greater portion of the colored curtain which is stretched in front of the lens; (4) the corneal chorioid, comprising the corneal endothelium lining the anterior chamber and its product, the posterior elastic lamina. These last have already been described.

This coat generally offers a marked contrast to the other two by its vascular and pigmented character, and has been compared to the pia mater of the brain. Its function is essentially nutritive, and it supplies the fluids that fill the eyeball and preserve its tension. It is soft, yielding, and easily torn or injured.

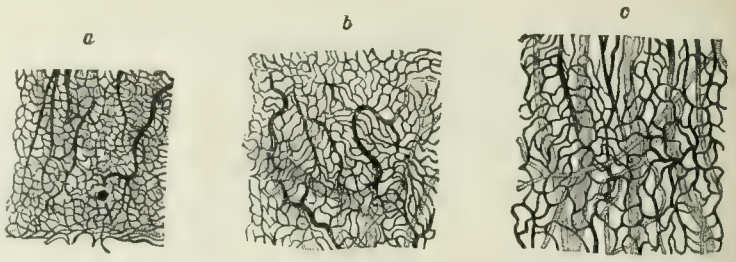


Fig. 2263.—The Capillary Network of the Chorioid. *a*, Near the optic-nerve entrance; *b*, about the equator of the eyeball; *c*, near the ora serrata. The veins are striated longitudinally, the arteries transversely, the capillaries are black. The latter are only half as broad as they ought to be.

The Chorioid Proper.—This portion of the middle coat, covering about two-thirds of the eyeball, is a loose, vascular, extensible tunic about 0.1 millimeter in thickness at the optic-nerve entrance, thinning gradually to about half that at the ora serrata. It is imperfectly separated from the sclera by the suprachorioidal space, intervening bands of fibrous tissue as well as numerous perforating vessels and nerves uniting the two. Its inner surface is smooth and closely applied to the pigmented layer of the retina.

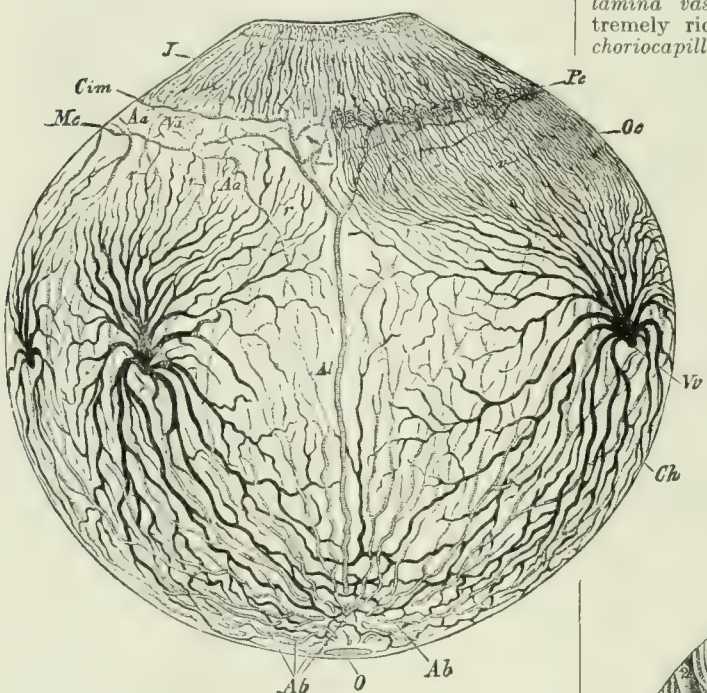


Fig. 2262.—Partially Diagrammatic Representation of the Course of the Vessels in the Chorioid. (Leber.) *Ch*, chorioid; *J*, iris; *Mc*, ciliary muscles; *Pc*, ciliary processes; *Oc*, ciliary ring; *O*, optic nerve entrance; *Ab*, short posterior ciliary arteries; *Al*, long posterior ciliary arteries; *Aa*, anterior ciliary arteries; *Cim*, greater arterial circle of iris; *Vv*, vorticose veins; *r*, *r*, recurrent arteries.

Its color, depending on the pigment deposited in its cells and the amount of blood in its vessels, is a dark or reddish brown, somewhat lighter in the old than in the young.

The general substance or *stroma* of the chorioid is composed of interwoven trabeculæ of connective tissue, both white and elastic, supporting a large number of blood-vessels and containing many irregularly branched, pigmented cells (Fig. 2259). The outer layer, being more loosely woven and containing fewer vessels, is known as the *lamina suprachorioidea;* that next to it, containing the largest vessels, is the *lamina vasculosa;* the next layer having an extremely rich network of capillaries is the *lamina choriocapillaris;* while the anhistous limiting membrane that separates this from the retina is the *lamina basalis* (Fig. 2260).

While the suprachorioidea is not itself remarkably rich in vessels and nerves, its loose tissue affords an avenue by which they readily penetrate to their ultimate destinations. The long ciliary arteries and nerves lie almost wholly in this layer in their transit forward to supply the iris and neighboring structures (Fig. 2261).

The arteries of the lamina vasculosa (Fig. 2262) are derived mainly from the short ciliary set that penetrate the ball by about twenty small branches in the vicinity of the optic nerve. The main vessels of this layer are, however, the vorticose veins, from four to eight large trunks formed by converging whorls of vessels. They are usually arranged in a nearly symmetrical manner in four sets about ninety degrees apart, and penetrate the sclera obliquely near the equator. Owing to this oblique penetration their discharge is liable to be interfered with by

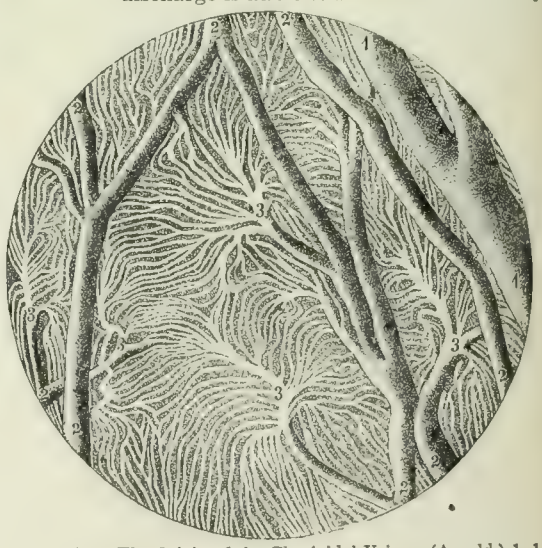


Fig. 2264.—The Origin of the Chorioidal Veins. (Arnold.) 1, 1, One of the larger veins; 2, 2, communicating veins; 3, 3, "Stars of Winslow," or vortical whorls of capillaries by which the veins arise from the choriocapillary layer.

pressure from without, particularly from the action of the ocular muscles. The veins are provided with perivascular sheaths that assist in maintaining an equable pressure. In the deepest part of this lamina are found wavy bundles of elastic tissue, a vestige of the *tapetum* that causes the metallic sheen observed in the eyes of many lower animals under certain conditions of reflected light.

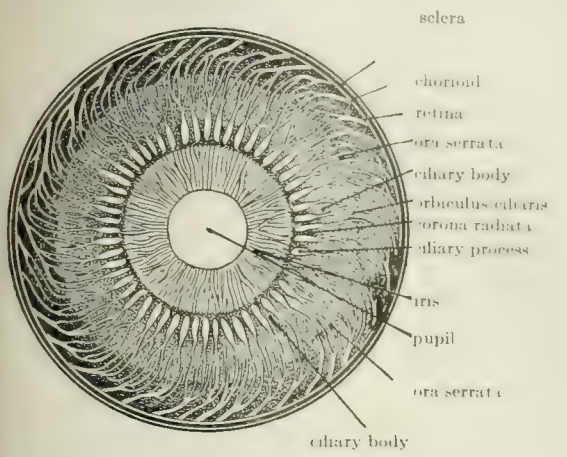


Fig. 2265.—The Ciliary Body as Seen from Behind. × 3.

The choriocapillaris or membrane of Ruysch (Fig. 2263) is a close-meshed network of capillaries, so close, in fact, that the space occupied by the vessels is greater than the intervals between them. This appears to be required for the nourishment of the closely contiguous percipient layer of the retina, *i.e.* the rods and cones, to which the proper arteries of the retina do not penetrate. The vorticose veins begin in this layer by capillary whorls, the *stellulæ vasculosæ*, sometimes called the *stars of Winslow* (Fig. 2264).

The basilar lamina, also known as the vitreous membrane, or the membrane of Bruch, is structureless or nearly so, and appears to be analogous to the basement membrane of epithelium.

The long and short ciliary nerves send vasomotor twigs to the chorioid, and lymphatics gather fluid from its numerous interspaces.

The Ciliary Body.—The wavy line of the ora serrata marks the limit of the layer of rods and cones of the retina and of its trophic layer, the choriocapillaris (Fig. 2264). From this line to the border of the iris curtain the middle tunic of the eye is marked by finely radiate striæ resembling cilia, hence the name that has been applied to this region. The posterior portion, comparatively smooth, is known as the *ciliary ring* or orbiculus ciliaris; the anterior portion, thickened and plicated in a meridional direction, is known as the *corona radiata*. Between these and the sclera, in the more superficial portion of the middle coat, lies an annular band of muscular tissue, known collectively as the *ciliary muscle*.

The ciliary ring, about 4 millimeters broad, is formed of nearly straight, unbranched vessels for conveying blood either forward to the corona radiata or backward to the vorticose veins, united by a loose stroma like that of other portions of the middle coat. The basilar layer is continued forward and is even somewhat thickened.

The corona radiata is the zone lying between the margin of the ciliary ring and the outer margin of the iris. It derives its name from the radiate arrangement of its characteristic features, the *ciliary processes*, club-shaped plications from 2 to 3 millimeters in length and 0.12 millimeters wide, that lie in a meridional direction (Fig. 2266). They resemble the glomeruli of the kidney in containing convoluted blood-vessels, and dentates [illegible] of the aqueous humor. [illegible] the lens (zonula ciliaris) [illegible] as far as the ora serrata, [illegible] directly from the stroma of the [illegible]. A [illegible] interval separates the [illegible] ciliary processes do not touch the lens but [illegible] distance of 0.5 millimeter from it.

The ciliary muscle (Fig. 2267) occupies a zone 6 to 7 millimeters in width and triangular in meridional section, reaching a maximum [illegible] meter. It takes its origin from the annular ligament and the sclera in the neighborhood of the [illegible] and is inserted upon the stroma of the middle coat in the region of the ciliary body and beyond. Its most superficial fibers are directed meridionally and constitute the *tensor chorioideæ* of Brücke; those next succeeding approach more and more a radial direction as they get deeper; and the deepest of all are arranged equatorially, constituting the *compressor lentis* of H. Müller. The office of the muscle is to draw the chorioid forward and thus relax the suspensory ligament of the lens, which, being no longer held tense, assumes a more convex shape suitable for the refraction of diverging rays from objects near at hand. In myopic eyes the circular fibers are fewer in number or wanting, while in hypermetropic eyes they are greatly increased.

Many ancient anatomists (Eustachius, Scheiner, Plempius, Descartes) suspected that this structure was muscular, but the first to demonstrate it from actual microscopic examination appears to have been an American oculist, William Clay Wallace of New York City, who, in 1835, published in the *American Journal of Sciences and Arts* an article "On the Accommodation of the Eye to Distances," saying:

"At the base of the ciliary processes, upon the inner surface of the chorioid coat, there is a range of muscular fibers. In the sheep the fibers of the upper portion run transversely to the ciliary processes; those of the lower portion run parallel to them."

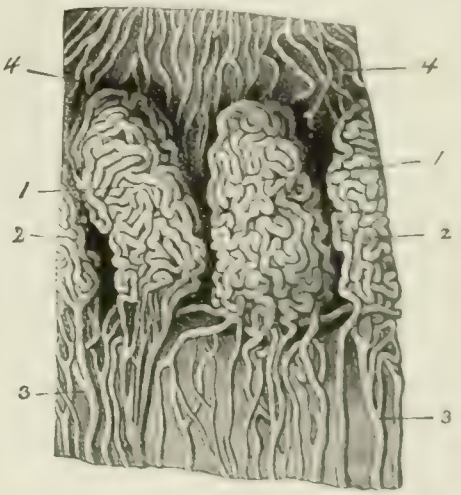


Fig. 2266.—Injected Ciliary [illegible] (Sappey.) 1, 2. Venous plexus [illegible] projections. 3, 3, efferent trunks [illegible] 4, 4, venous radicles from the iris. × 12.

Brücke, to whom the credit of the discovery of the meridional fibers is usually given, did not describe the muscle until 1846, and H. Müller [illegible] with the discovery of the equatorial fibers, published first in 1855.

The muscle is supplied by the long ciliary nerves from the nasal branch of the ophthalmic and by the

short ciliary from the ciliary ganglion. These form within the substance of the muscle a ring-like plexus, the *ciliary plexus* (orbiculus gangliosus), from which pass fibers of apparently motor function, ending free between the muscle cells, vasomotor fibers, and also sensory fibers with terminal end organs. Some of the latter are believed to impart an accurate appreciation of the contraction of the muscle.

millimeters in diameter, according to the state of contraction of the iridial muscles.

It will be remembered that the pupillary border of the iris forms the edge of the optic cup, which here doubles back upon itself and becomes invested by the vascular, mesodermal layer that produces the chorioid. Hence the iris is composed of two genetically distinct portions: a retinal one, secondarily

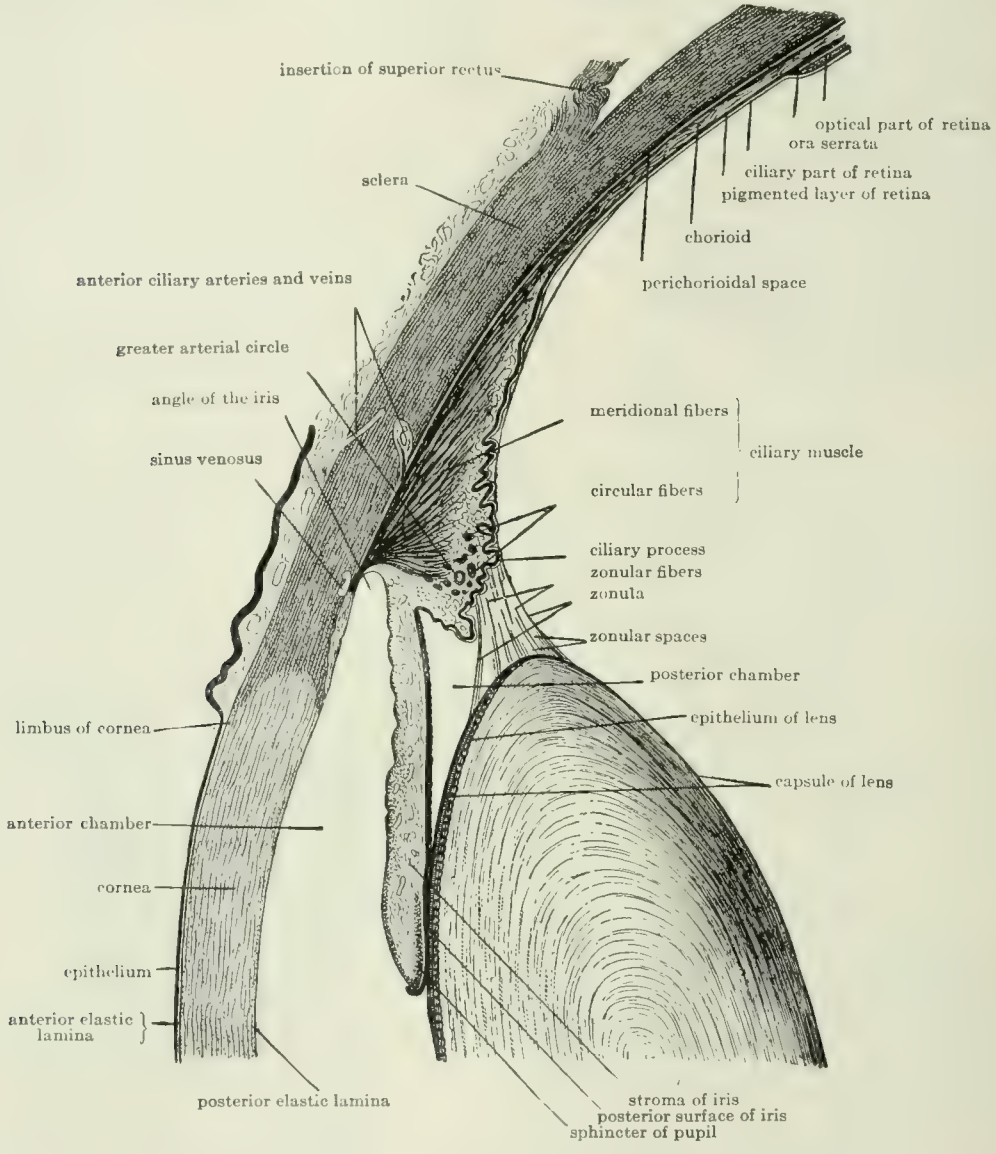


Fig. 2267.—Meridional Section of a Portion of the Anterior Part of the Eyeball. (Toldt.)

The Iris.—This colored diaphragm, pierced with its central aperture, the pupil, hangs freely but not quite vertically in the aqueous chamber, its outer or ciliary border attached just behind the corneoscleral junction, and its free or pupillary border resting a little anterior to the other upon the lens. Behind, its tissue is continuous with that of the ciliary body, in front with that of the pectinate ligament and the angle of the iris.

Its diameter is from 10 to 12 millimeters, its thickness 0.4 millimeter when lax, increasing to double that amount when contracted. The pupil, slightly eccentric toward the nasal side, varies from 1 to 8

derived from the ectoderm, belonging to the optic cup proper; and a chorioidal one, mesodermic in origin (Fig. 2268). Since the retinal portion contains no percipient elements it will be convenient to consider all together.

Viewed closely, the anterior surface will be seen to present two concentric zones, *pupillary* and *ciliary*, separated by a festooned line, the *lesser arterial circle*, that indicates the former attachment of the pupillary membrane (Figs. 2269 and 2270). Both zones are marked by radial striæ, caused by vessels and nerves: those of the pupillary zone being fine and close

radii minores; those of the ciliary zone larger, *radii majores.* The pupillary border shows a thin black line slightly beaded where the striæ reach it. In the pupillary zone there are found between the striæ minute clefts that penetrate the stroma and com-

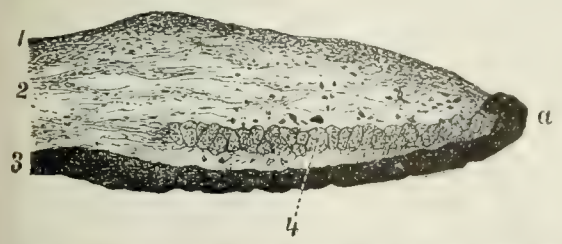


Fig. 2268.—Meridional Section through the Pupillary Zone of the Human Iris. *a*, Pupillary border formed of epithelium, arranged in bead-like processes; 1, anterior limiting layer; 2, stroma or vascular layer; 3, pigmented epithelium, continuous behind with the retina; 4, sphincter pupillæ.

municate with lymph spaces. The ciliary zone is furrowed by concentric ridges that indicate where folds are formed during dilatation.

Pigmented cells scattered through the stroma impart color. When these are scanty the pigment of the posterior epithelium shows through, producing the color characteristic of blue or gray eyes according to the thickness of the translucent stroma. The stroma pigment is scattered in flecks, producing various tints of green, yellow, or brown which when very deep is called black. In albinos pigment is absent even in the posterior epithelium and the iris appears reddish from the hue of its blood-vessels.

The posterior surface (Fig. 2271) presents a series of radial ridges cut by concentric lines into rectangu-

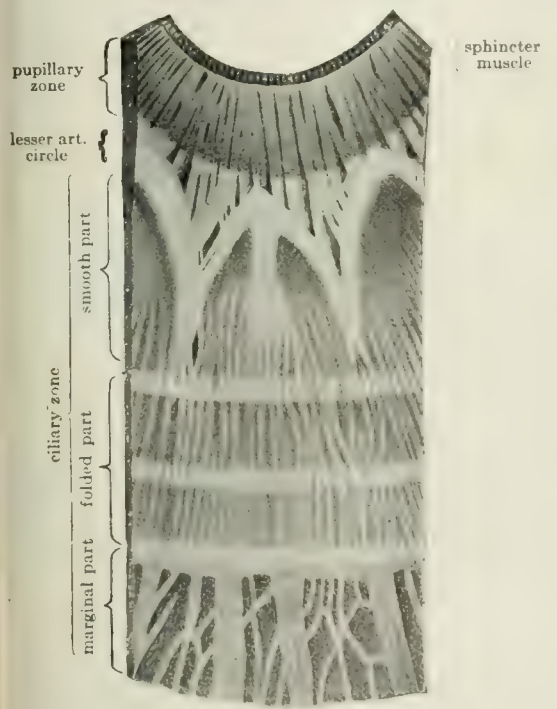


Fig. 2269.—Segment of Anterior Surface of Iris with Pupil Contracted. × 20. (Fuchs.)

lar spaces. Within the pupillary zone these ridges (*contraction folds*) are increased in number. The color of the posterior surface is normally uniform and dark from the pigmented retinal epithelium.

In minute structure the iris consists of a [illegible] portion, composed of a loose stroma [illegible] both externally and internally to a boundary membrane and clothed also anteriorly with the endothelium of the anterior chamber, and of a retinal portion,

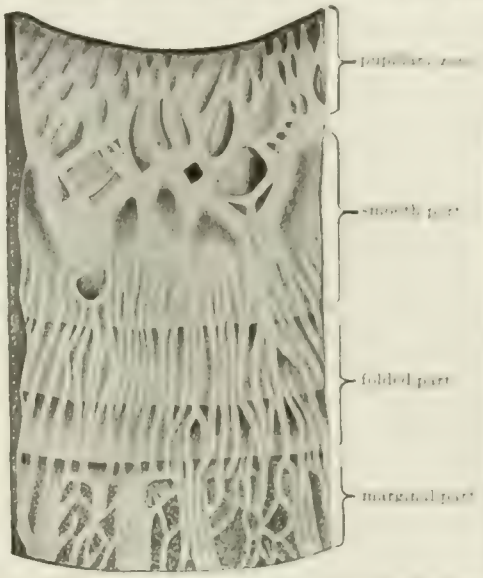


Fig. 2270.—Segment of Anterior Surface of Iris with Pupil Dilated. × 20. (Fuchs.)

composed of two layers of pigmented cells corresponding to the reflected margin of the optic cup.

The anterior epithelium, clear and transparent, is like that lining the posterior surface of the cornea.

The anterior boundary layer is composed of delicate interlacing bundles essentially similar to the connective tissue of the stroma.

The stroma is much like that of the chorioid, being composed of numerous vessels and nerves united by loose connective tissue, with interstitial lymph spaces and muscular fibers. The latter are condensed near the pupillary margin to an annular band, the *sphincter pupillæ*, while an imperfect layer of radially arranged bundles stretching from the sphincter to the pectinate ligament constitutes the *dilatator pupillæ*. The long controversy regarding the existence of these fibers, which are very difficult to demonstrate in the pigmented iris, may now be regarded as settled. The sphincter appears to be controlled by the oculomotor nerve, the dilatator by the sympathetic.

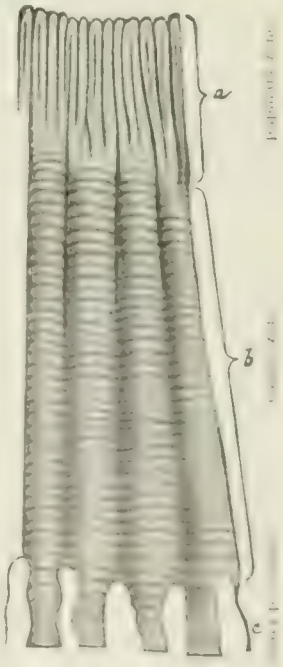


Fig. 2271.—Segment of Posterior Surface of Iris. Medium Dilatation. Pupil [illegible] × 25. (Fuchs.)

The posterior boundary layer is a continuation of the basilar lamina of the chorioid and like it is a very thin structureless membrane

formed by condensation of the connective tissue of the stroma.

The epithelium of the retinal portion of the iris is in two layers, of which the outer is composed of fusiform cells, the inner of columnar cells. Both of these are densely crowded with pigment.

A vascular network, the greater arterial circle (Fig. 2272), formed by branches of the anterior and long ciliary arteries, lies at the ciliary border of the iris between the two portions of the ciliary muscle. From this arterioles pass radially toward the pupil and on reaching the sphincter unite in another anastomosis, the lesser arterial circle, from which are given off vessels that supply the pupillary zone and the pupillary membrane of fetal life. Venules from these networks pass radially outward and finally discharge into trunks that reach the vorticose veins.

There are abundant lymph spaces within the stroma of the iris, but no lymphatic vessels properly speaking. The nerves of the iris are derived from the ciliary plexus. Their fibers, as they proceed toward the pupillary border, form a coarse meshwork from which are derived motor nerves with ultimate filaments that supply muscle cells, vasomotor nerves, and sensory nerves that lie immediately under the anterior endothelium.

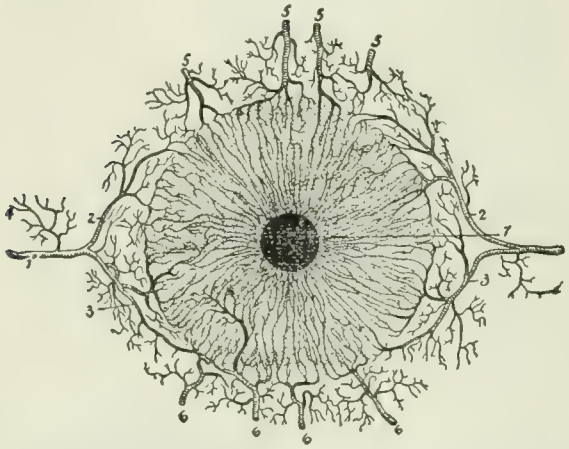


Fig. 2272.—Arteries of the Iris. (Sappey.) 1, 1, Long posterio ciliary arteries; 2, 3, their branches of bifurcation; 4, recurren arteries destined for the chorioid; 5, 5, 6, 6, anterior ciliary arterie anastomosing with the long ciliary to form the greater arteria circle of the iris; 7, the lesser arterial circle of the iris.

The Inner or Nervous Coat.—Being formed from the duplicate, invaginated layers of the optic cup, originally an outgrowth from the brain, the structure of this coat bears some analogy to that of the cerebral cortex. As the ventricles of the brain are lined with epithelium (ependyma), so the lining of the cavity of the optic vesicle, originally continuous with them, retains an epithelial character. By the invagination of the optic cup this cavity becomes obliterated, but the boundary lining remains as the two outer layers of the retina. The outermost of these is a single layer of highly pigmented epithelium; the inner one becomes, for a region extending from the optic-nerve entrance to the ora serrata, a highly specialized neuro-epithelium reinforced by a large number of nervous elements, while over the ciliary region and the iris it too is reduced to a single layer of simple epithelium, non-pigmented in the former, pigmented in the latter region.

We may therefore distinguish three retinal regions: (1) The retina proper, or percipient retina; (2) the ciliary retina; and (3) the iridian retina. The last has already been described.

The Retina Proper is a smooth tunic that covers the posterior two-thirds of the interior of the eyeball, reaching to about 5 millimeters from the attachment of the iris. When the interior of the eye is viewed by the ophthalmoscope it appears reddish from the blood-vessels that ramify in the innermost layers. Its thickness varies from 0.4 millimeter behind to half that near the ora serrata. Its outer epithelial

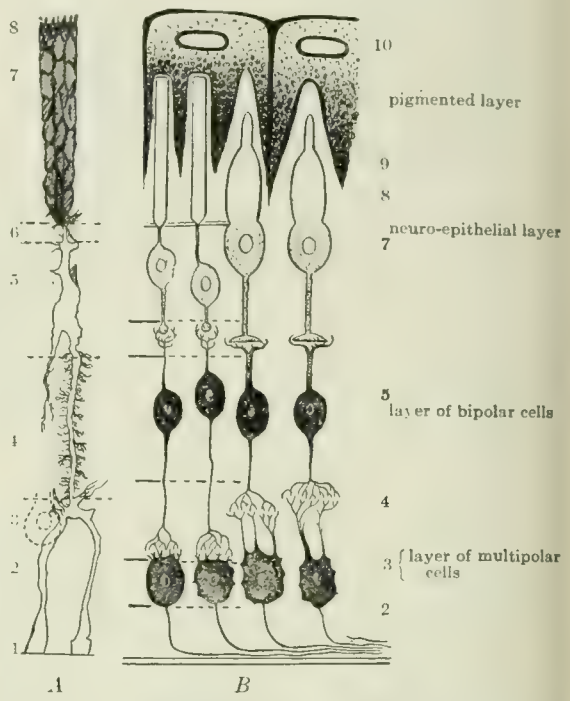


Fig. 2273.—Schema Showing the Arrangement of the Structural Elements of the Retina. *A*, Fiber of Müller; *B*, nerve and epithelial cells. 1, Membrana limitans interna; 2, layer of nerve fibers; 3, ganglionic layer, 4, inner molecular layer; 5, inner nuclear layer; 6, outer molecular layer; 7, outer nuclear layer; 8, membrana limitans externa; 9, layer of rods and cones; 10, pigmentary layer.

layer is deeply pigmented, the remainder perfectly transparent unless deprived of light, when it assumes a purplish hue due to a diffused coloring matter known as the visual purple (*rhodopsin*). Its transparency ceases after death and sometimes during life from pathological causes. It is also normally obscured where the fibers of the optic nerve enter—the *optic papilla*, and in an elliptical area lying in the optical axis—the *yellow spot*.

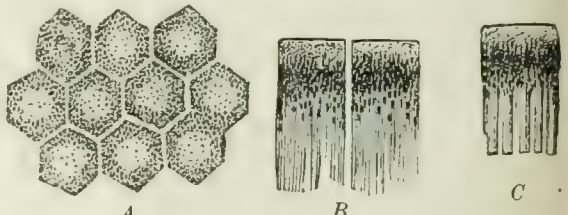


Fig. 2274.—Cells of Pigment Epithelium from the Human Retina. (Max Schultze.) *a*, Surface view; *b*, side view showing fringe-like processes that extend toward the layer of rods and cones; *c*, a cell to which the outer portions of some rods are attached.

The optic papilla (optic disc, porus opticus), situated 1 millimeter below the horizontal meridian and 3 millimeters to the nasal side of the vertical meridian, is nearly circular in form with a diameter of from 1.4 to 1.7 millimeters. As the optic fibers pass through the lamina cribrosa they lose their medullary

sheaths and diverge, causing a depression near the center of the disc, termed the *excavation.* The

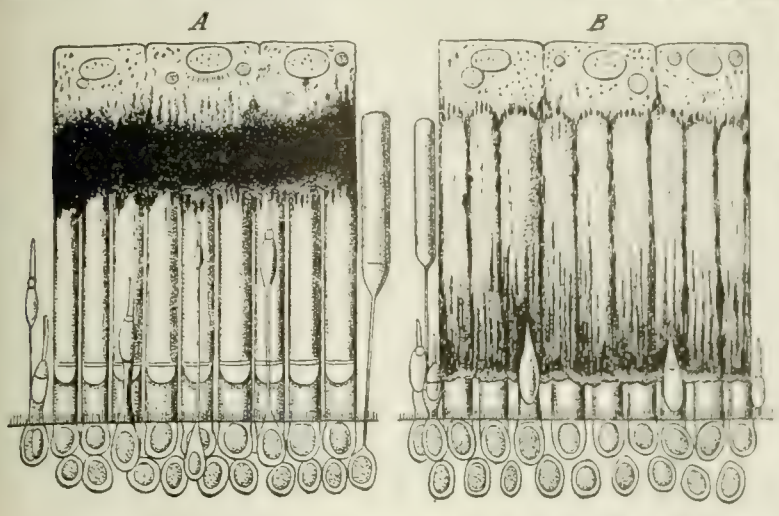


FIG. 2275.—Sections of Frog's Retina Showing the Action of Light upon the Pigment Cells, and upon the Rods and Cones (von Gendesen—Stort.) *A*, From a frog which had been kept in the dark for some hours before death; *B*, from a frog which had been exposed to light just before being killed. Three pigment cells are shown in each section. In *A* the pigment is collected toward the nucleated part of the cell, in *B* it extends nearly to the basis of the rods. In *A* the rods, outer segments, were colored red (the detached one green), in *B* they had become bleached. In *A* the cones, which in the frog are much smaller than the rods, are mostly elongated, in *B* they are all contracted.

myelin of the deep fibers shining through its transparent surface gives a whitish appearance to the disc and the free edges of the sclera and chorioid are seen as boundary rings. The central artery of the retina entering at the excavation ramifies upon its surface. There being no percipient elements in this area it is insensible to light, and is hence sometimes called the punctum cæcum or blind spot.

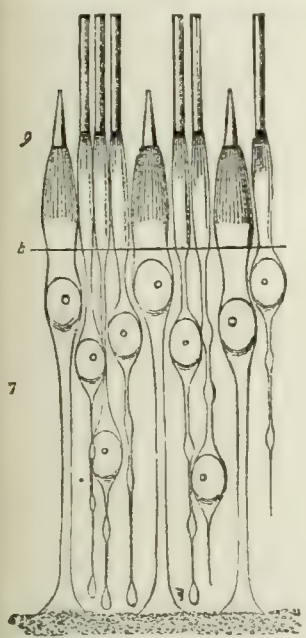
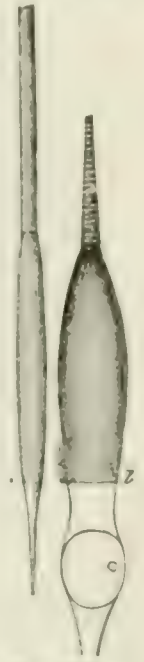


FIG. 2276.—Neuro-epithelium of the Human Retina. (Max Schultze.) 6, Arborescent processes, forming the appearance known as the "external molecular layer"; 7, nuclei of the epithelial cells, forming the "external nuclear layer"; 8, grill-work formed by processes of the fibers of Müller, forming the "membrana limitans externa"; 9, specialized processes of the epithelium, forming the layer of rods and cones.

The yellow spot (*macula lutea*, spot of Sömmering) is a reddish-brown area nearly circular in form, about 2 millimeters in diameter. Near its center it has a depression termed the central fovea (*fovea centralis*), 0.02 to 0.4 millimeter in diameter, which is the seat of the most acute vision. The percipient elements have here a special arrangement which will be hereafter described. Rhodopsin is wanting here.

The retina being the only sense organ directly derived from the cerebral cortex, shows considerable [illegible] usually widely separated. [illegible] three layers that communicate with each other in a chain-like sense. All [illegible] the neuroglia [illegible] and cones that receive the primary impulses leading to [illegible] (2) true [illegible] sometimes collectively called the ganglion of the retina. (3) Liminal, large multipolar cells lying near the inner surface of the retina and sending fibers brainward through the optic nerve.

Similar members exist in other sense organs; thus, in the organs of common sensation we have; (1) the epithelium surrounding the nerve terminal in the skin; (2) the cells of the spinal ganglia, conveying the impulses to the nervous centers; (3) the cells of the receptive nuclei in the spinal cord or the medulla oblongata.



[illegible]

Besides the elements of the retina already mentioned, which are doubtless the main apparatus by which visual sensations are conveyed, there are certain associative cells that probably serve to correlate and coordinate the action of the separate neural chains.

All these may be considered active elements. There are also, in the central nervous system, certain passive or sustentacular elements. These, known in other regions as neuroglia cells, are in the retina called the fibers of Müller.

The retina is often described as consisting of from nine to eleven layers. There seems to be no good

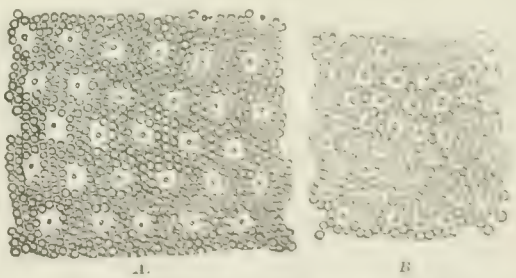


FIG. 2278.—Distribution of the Rods and Cones. *A*, From the peripheral portion of the retina. *B*, [illegible]

reason for this, as some of the [illegible] as layers are caused by the [illegible] of cells, while others, the [illegible] are expansions from the [illegible] of Müller. Morphologically speaking [illegible]

four layers, the three already mentioned and the external layer of pigmented epithelium. The accompanying diagram presents both the older and the more recent nomenclature (Fig. 2273). The layers will be described in succession from without inward.

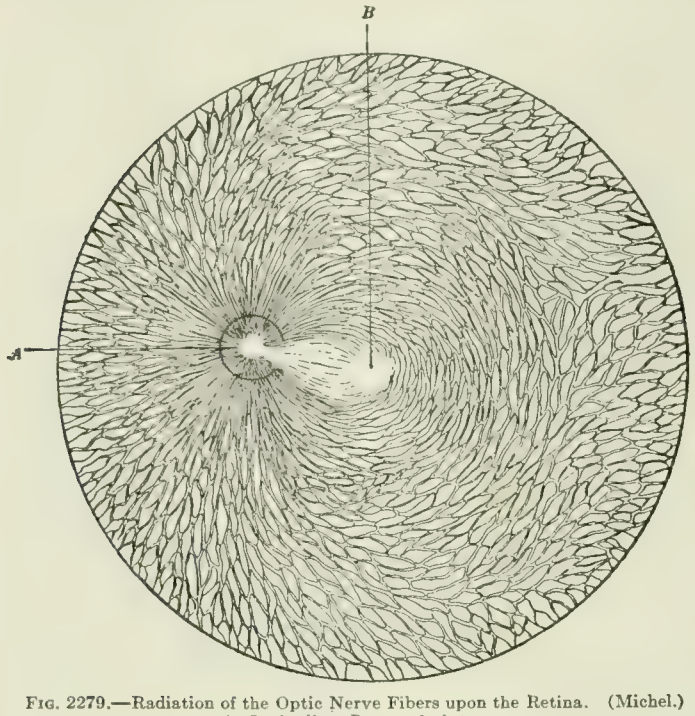


Fig. 2279.—Radiation of the Optic Nerve Fibers upon the Retina. (Michel.) *A*, Optic disc; *B*, macula lutea.

The pigmented layer comprises the entire outer lamella of the optic cup, the part not invaginated in the course of its development, and is composed of a single layer of tesselated polygonal cells (Fig. 2274), whose protoplasm is crowded with colored granules (the fuscin of Kühne), which have the form of minute crystals with long axes perpendicular to the retinal surface. They are somewhat more deeply colored near the ora serrata. The outer surface of the cells, applied to the basilar lamina of the chorioid, is smooth and devoid of pigment; the inner surface is not well defined, for it consists of fringe-like filaments loaded with pigment that extend down between the outer segments of the rods and cones which are applied directly against it. Experiments have shown that the distribution of the coloring matter in these cells varies with exposure to light, for during prolonged darkness it is withdrawn into the cell bodies, while after the stimulus of light it descends like a curtain into the fringe between the rods and cones (Fig. 2275). The visual purple (*rhodopsin*) found in the outer segments of the rods appears to be derived from the pigmented layer.

The neuro-epithelial layer, or layer of visual cells proper, comprises two distinct elements, the rod cells and the cone cells (Fig. 2276), set in a framework (external limiting membrane) formed by processes from the fibers of Müller, and projecting into the pigmented fringe already described. These cells are bipolar in form, having elliptical cell bodies (rod and cone granules) with large nuclei surrounded by a small amount of protoplasm from which processes extend radially in either direction. The outer one of these expands into the peculiar bacillary forms known as the rods and cones; the inner one extends inward for a short distance and ends either in a rounded knob (rod cells) or an expanded foot (cone cells) embraced by the filamentous terminals of the ganglion cells of the next layer.

The bodies of the rod cells, which lie at various levels, show when stained under favorable conditions dark and light bands. The rods themselves are divided into two nearly equal segments: an outer, cuticular, doubly refracting one, and an inner, protoplasmic singly refracting one; the former being cylindrical, staining but slightly and having a tendency to break up into superimposed discs; the latter slightly elliptical in outline, staining readily and showing at its outer end a fibrillated area called the ellipsoid, more apparent in the lower animals than in man (Fig. 2277). The outer segments are purplish-red in tint, owing to the diffusion through them of *visual purple* or rhodopsin, the peculiar coloring matter of the retina, which quickly bleaches in the presence of light.

The bodies of the cone cells (Fig. 2276) are contiguous to their bacillary processes or cones. The latter also have an outer and an inner segment. The outer segment, apparently similar in intimate structure to that of the rods, is, however, much shorter, ending in a blunt point. The inner one, thick and flask-shaped, contains also an ellipsoid. During prolonged darkness the cones appear to stretch outward toward the pigmented layer (Fig. 2275). They do not contain rhodopsin.

The distribution of the rods and cones varies in

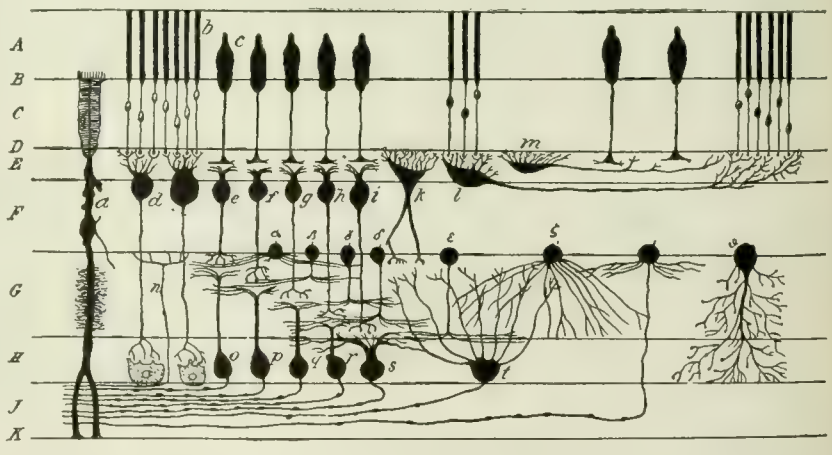


Fig. 2280.—Diagram Illustrating the Relation of the Retinal Elements. (Kallius.) *A*, Layer of rods and cones; *B*, limitans externa; *C*, outer nuclear layer (bodies of visual cells); *D*, Henle's external fibrous layer (composed principally of rod fibers); *E*, outer plexiform layer; *F*, inner nuclear layer (rod and cone bipolars); *G*, inner plexiform layer; *H*, layer of large ganglion cells; *J*, fiber layer; *K*, limitans interna; *a*, supporting fiber of Müller; *b*, *c*, rod and cone visual cells; *d*, bipolars belonging to rod cells; *e–i*, bipolars belonging to cone cells; *k–m*, horizontal nerve cells; *n*, centrifugal nerve fiber; *o–t*, ganglion cells connected with optic fibers; *α–ε*, amacrines arranged in layers; *ζ–ϑ* diffuse amacrines *η*, nervous amacrine.

different parts of the retina and in different animals (Fig. 2278). In the central fovea, the region of the most acute vision, cones only are found, but from this point forward the proportion of rods gradually increases, until at the ora serrata cones are almost wholly absent. It is estimated by Krause that there are in the retina about 7,000,000 cones, or seven to each fiber of the optic nerve, and that the number of rods is about 130,000,000. While in fishes the rods far exceed the cones in number, in birds and reptiles the reverse is the case, lizards possessing cones alone. As cones are often wanting in nocturnal animals and decrease in the peripheral portion of the retina where color perception is least, it is thought that it is by them that colors are distinguished.

In the layer of bipolar cells the characteristic elements are fusiform with protoplasmic processes that surround the inner terminals of the visual cells. They may therefore be distinguished as rod bipolars and cone bipolars according as they are related to the rod or to the cone cells. The rod bipolars have protoplasmic processes with vertical arborizations, embracing from three to twenty bases of rod cells, and long axis-cylinder processes that penetrate centrally

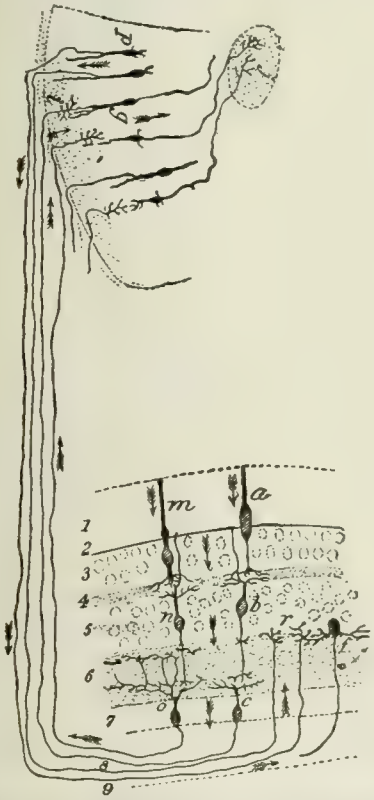


Fig. 2281.—The Course of Nerve Fibers Between Retina and Brain. (Ramón y Cajal.) *A*, Retina; *B*, corpus geniculatum; *j*, central ganglion; *a*, *b*, *c*, a cone system composed of a rod, a bipolar cell, and a multipolar cell; *m*, *n*, *o*, a rod system composed of a rod, a bipolar cell, and a multipolar cell; *g*, cells of the corpus geniculatum that receive excitations from the retina through the optic nerve; *p*, *q*, *r*, a centrifugal current originating in the brain and passing to the retina.

as far as the bodies of the multipolar cells, around which they ramify. The cone bipolars have protoplasmic processes, with horizontal arborizations that interblend with twigs from the feet of several cone cells, probably including also in their contact area some of the terminations of the rods. Their axis-cylinder processes are much shorter than those of the rod bipolars and terminate on [illegible] determinate levels by blending with [illegible] processes of the cells of the next layer.

The layer of multipolar cells consists of large, irregularly oval elements with protoplasmic processes that intertwine with arborescences of [illegible] outer layers, and whose axis-cylinder [illegible]

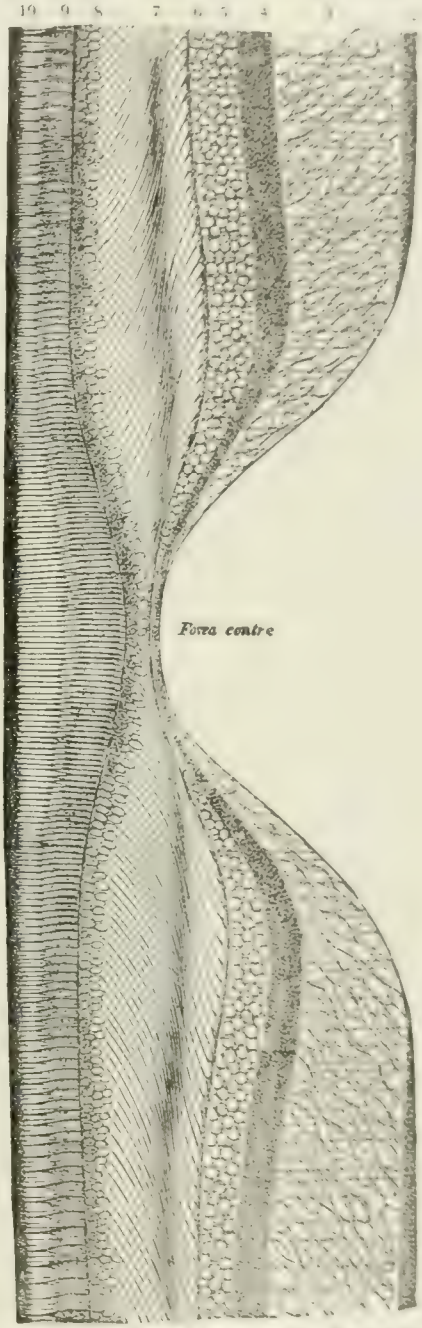


Fig. 2282 Diagrammatic [illegible] Fovea Centralis. 2, [illegible] cells; 4, internal molecular [illegible] escent processes. 5, layer of [illegible] layer; 6, external molecular [illegible] horescent processes. 7, [illegible] layer; 8, grillwork formed by processes from fibers of Müller, often called the "external limiting membrane"; 9, layer of rods and cones; 10, layer of pigment epithelium.

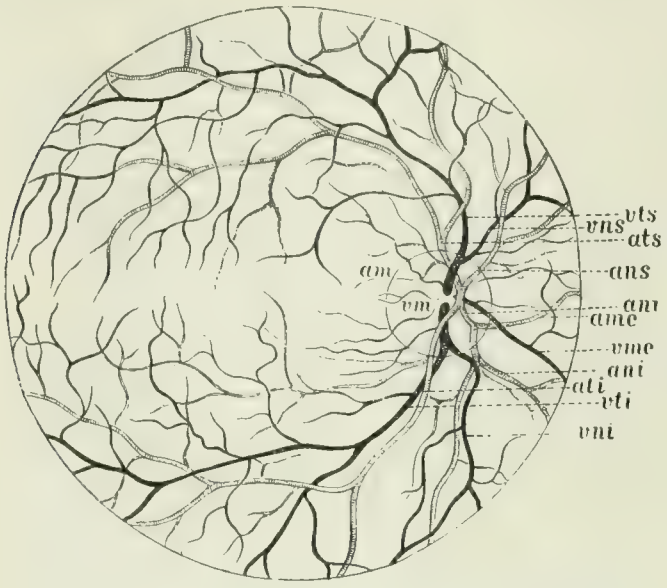


Fig. 2283.—Diagram of the Blood-vessels of the Human Retina. (Leber, after Jaeger.) *ans*, *vns*, Superior nasal artery and vein; *ats*, *vts*, superior temporal artery and vein; *ani*, *vni*, inferior nasal artery and vein; *ati*, *vti*, inferior temporal artery and vein; *am*, *vm*, macular artery and vein; *ame*, *vme*, median artery and vein.

toward the optic disc and become fibers of the optic nerve (Fig. 2279). The cells of this layer are classified according to the arrangement of their protoplasmic processes: (1) monostratified, those whose processes ramify in but one level; (2) multistratified, those whose processes ramify in more than one level; (3) diffuse, those whose protoplasmic arborescences are not limited to definite levels.

At two different levels of the retina associative cells are found: (1) in relation to the rod and cone cells; (2) in relation to the layer of bipolar cells (Fig. 2280). The first class run parallel to the layers of the retina and hence are often called *horizontal* cells, three varieties of which are distinguished: one small, flattened, stellate, *cone associatives*, connecting cone terminals with each other; another larger and placed somewhat deeper, *rod associatives*, connecting by means of long axis-cylinder processes rod terminals; a third, large, pyriform in shape, having descending processes that pass centralward as far as the internal ramifications of the bipolar cells.

The second class of associative cells is situated in the internal portion of the layer of bipolar cells, constituting there what some authors recognize as a distinct layer of the retina. W. Müller, supposing them to be of a sustentacular character, called them spongioblasts. It seems desirable to discontinue the use of this name as it has been applied by His to totally different structures, the primitive cells of the medullary plate from which neuroglia is formed. Ranvier, who regarded these elements as undoubtedly nervous, designated them as unipolar cells. Cajal, having in view the fact that they do not show any axis-cylinder process of the typical form, called them *amacrine* cells, from α privative; μακρός, long; ἴς, ἰνός, nerve—*i. e.* having no long process. The name is not wholly satisfactory, as homologous structures in reptiles and birds undoubtedly possess a distinct axis-cylinder process, and in man a considerable difference is noted in the ramifications on two sides of the cells.

These cells are large and pyriform with arborescent processes extending inward, and may be subdivided into *diffuse* amacrines that send ramifications throughout all levels where the terminals of the bipolars branch, and *stratiform* amacrines that confine their ramifications to one of the five levels at which the cone bipolars terminate. Their terminal filaments appear to embrace the inosculations of the bipolar and multipolar cells.

It will be remembered that the greater part of the fibers of the optic nerve originate as outgrowths from the cells of the retina. Some "centrifugal"

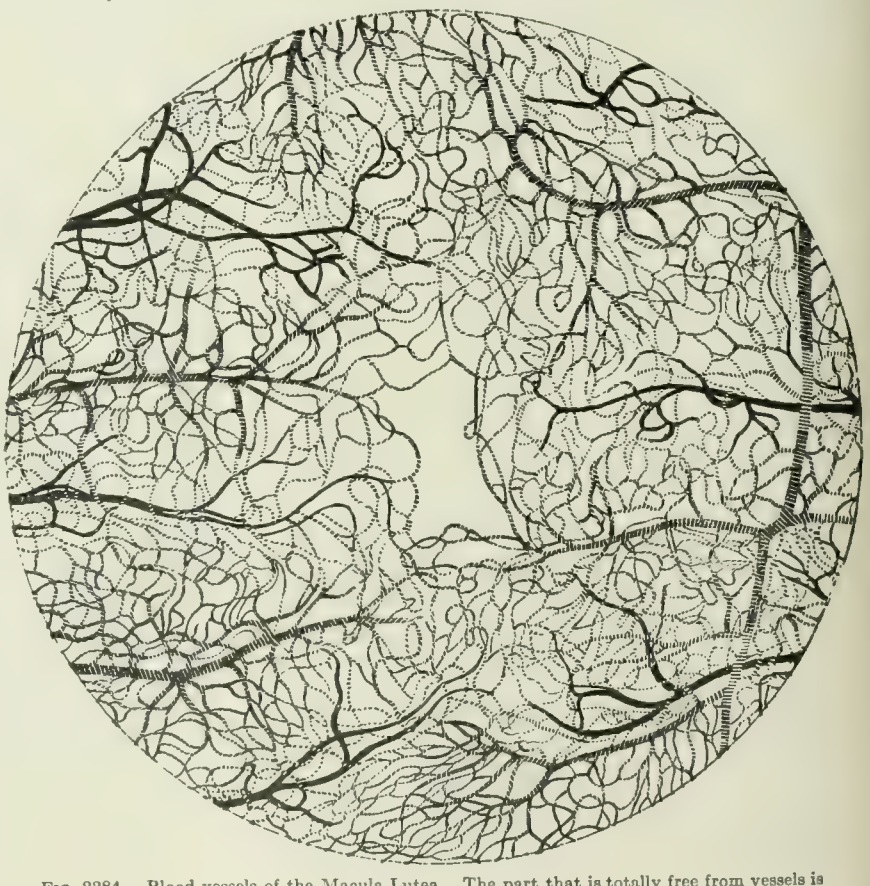


Fig. 2284.—Blood-vessels of the Macula Lutea. The part that is totally free from vessels is the fovea centralis.

fibers do however, occur, probably for conveying impulses from the brain to the retinal cells (Fig. 2281). Some of these end by ramifications about the amacrine cells, others at various levels by horizontal arborescence.

During the early development of the neural tube certain cells, called by His spongioblasts, become shaped into rods extending throughout the entire thickness of the wall of the tube and constituting, by interlacing processes, an efficient framework for supporting the delicate protoplasmic nerve cells that they surround. These elements remain as the neuroglia of adult nervous tissue. The retina shows its genetic relation to the medullary tube by the possession of similar sustentacular elements which are known as the *fibers of Müller* and the *spider cells*.

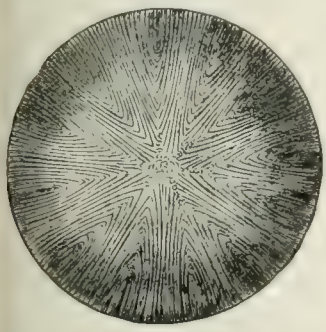


Fig. 2285.—Anterior Surface of Adult Lens. (Arnold.)

The fibers (Fig. 2280) extend radially throughout all portions of the percipient retina, being especially well marked near the ora serrata and in the macula lutea. They are greatly modified and elongated cells, whose nuclei lie at the level of the layer of bipolar cells. At the internal surface of the retina they commence by broad and often forked bases that unite with each other to form a continuous boundary known as the *internal limiting membrane*, which, however, cannot in any way be considered to be an independent structure. At their distal or external ends they unite to form a grillwork around the rods and cones which project beyond them. This fenestrated structure is inaptly called the *external limiting membrane*. Septa from the fibers closely invest the bodies of the visual cells, and delicate lateral processes are also given off by them for the support of the terminals of the bipolar, multipolar, and amacrine cells.

Stellate neuroglia or spider cells are found near the inner surface of the retina between the bundles of nerve fibers and among the multipolar cells.

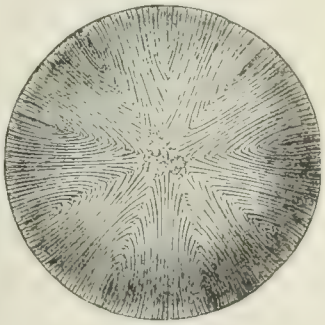


Fig. 2286.—Posterior Surface of Adult Lens. (Arnold.)

The structure of the retina in the macula lutea and fovea centralis varies somewhat from that already described (Fig. 2282). In the fovea the cones are the only visual cells found, being there much narrower and longer than in other regions. The conical depression of the fovea causes the fibers of the cells to be drawn out obliquely. The bipolar and multipolar layers disappear at the center of the fovea, but immediately about it, within the macula, become increased in thickness.

The Ciliary Retina.—As we approach the ciliary region the highly specialized structures that characterize the fundus of the retina become changed. The cones become more scanty, the multipolar cells are fewer, the rods are shortened and disappear. Finally, the elements are abruptly reduced to a simple layer of columnar epithelium. This sudden diminution leaves a line of [illegible] at the ora serrata, well seen by the [illegible] eye.

The retinal blood-[illegible] from the central artery of the retina, which, as already stated, pierces the nerve at [illegible] millimeters behind the eyeball and [illegible] disc at the bottom of the [illegible] breaks up into two branches, the *superior* and *inferior papillary arteries*, each of which subdivides into a temporal and a nasal branch. The papillary arteries also send small twigs, the *macular arteries*, toward the region of the yellow spot. Except at the optic-nerve entrance, where a capillary anastomosis occurs with twigs from the posterior ciliary arteries, all these vessels form a system independent of that of the chorioid. They ramify mainly in the layer of multipolar cells and do not anastomose with each other. At the central fovea the vessels from this system are wanting (Fig. 2284), as might be expected from the absence of the inner layers at that place.

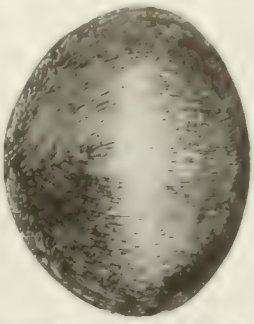


Fig. 2287.—[illegible] at Birth Seen from the Side. (Arnold.)

The *crystalline lens* (Figs. 2285, 2286, 2287), is a transparent biconvex body with a circular margin, applied to the opening of the pupil, touching the iris in front and resting behind in a shallow depression of the vitreous, known as the *hyaloid fossa*. Its margin is from 0.5 to 0.6 millimeter, from the ciliary processes to which it is united by a suspensory ligament called the *zonula*. Its diameter is from 9 to 10 millimeters, and, having the unique property of changing its form under the influence of the ciliary muscle for adaptation to vision of near or remote objects, its thickness varies from [illegible] to 4 millimeters. While not mathematically exact, its curved surfaces are nearly those of spheres, the radius of the anterior one varying from 10 to 6 millimeters, that of the

Fig. 2288.—Meridional Section Through Lens of Calf. (Arnold.)

Fig. 2289.—[illegible] Lens. (Arnold.)

posterior one from 6 to 5 millimeters, according as the lens is accommodated for distant or near objects. The fetal lens is nearly circular; in old age it becomes flattened.

The weight of the adult lens is from 0.20 to 0.25 grams, specific gravity 1.121, volume 0.25 c.c. The central core or *nucleus* is more condensed and less elastic than the peripheral part or *cortical substance*, though its histological structure is the same. This difference does not exist in the fetus and increases

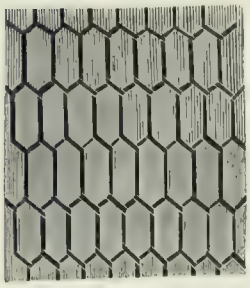


Fig. 2290.—Section of Frozen Lens Showing Hexagonal Shape of Fibers. (Arnold.)

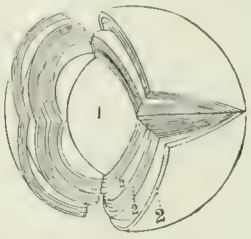


Fig. 2291.—Lamination of the Lens as Shown After Treatment with Dilute Alcohol. (Arnold.) 1, Former central portion called the nucleus lentis; 2, 2, layers of the so-called cortical substance.

with age, depriving the lens of its elasticity, so that the eyes of elderly persons do not readily accommodate for distance. The nucleus refracts more than the cortical substance, the indices being 1.4541 and 1.4053 respectively, that of distilled water being 1.3342 (Krause). The lens is completely enveloped by a structureless elastic capsule thicker in front than behind, which resembles in its reactions the sarcolemma of muscle or the membrana propria of glands.

The development of the lens is the key to its structure. It will be remembered that it is formed from an invagination of the external epithelium that becomes isolated as the lenticular vesicle and that the cells of the anterior wall retain their epithelial characters, becoming more and more columnar toward the margin or equator of the lens, while those on the retinal aspect become lengthened into flattened fibers that vary in size and length in the central and the peripheral portions (Fig. 2288). The superficial fibers are from 0.010 to 0.012 millimeter wide, 0.005 millimeter thick, and 8 millimeters long, while those of the deeper portion are 0.0075 wide, 0.0025 thick, and 4 millimeters long. In the middle and interior portions of the lens the edges of the fibers are finely serrated (Figs. 2289, 2290), but these serrations do not fit into each other and there are thus left between the fibers fine spaces that serve for the passage of lymph. As the lens has no blood-vessels such a provision seems necessary for its nutrition. Between the epithelium and the lens fibers is the original cavity of the lenticular vesicle reduced to a narrow slit filled with semi-fluid material. This rapidly liquefies after death and becomes the so-called *liquor Morgagni*.

When treated by appropriate reagents the fibers of the peripheral third of the lens may be separated into concentric layers like those of an onion (Fig. 2291). In each layer the fibers have approximately the same length and terminate along nearly regular radiating lines (*radii lentis*) producing the so-called *lens stars* (Fig. 2292). In the young lens these have behind an arrangement like a Y, in front that of the same letter reversed (⅄). They are more complicated in the adult.

The anterior chamber has the character of a lymph space developed in the connective tissue that primitively separates the lens from the external epithelium. This cavity is filled by the *aqueous humor*, a sparkling, transparent fluid containing 98.71 per cent. of water and having a considerable similarity to lymph. The quantity of this is from 231 to 323 cubic millimeters and remains nearly constant during life, being sufficient to maintain an intraocular tension equal to that of a column of mercury 26 millimeters in height. Its specific gravity is 1.0053 and its index of refraction 1.3420, that of distilled water being 1.3342 (Krause). Apparently it is constantly renewed by a secretion from the vessels of the chorioid, particularly those of the ciliary processes, and removed from the chamber by infiltration through the spaces of the angle of the iris into the scleral sinus and perhaps by the lymph crypts of the iris. Normally it contains no morphological elements.

Behind the lens the cavity of the eyeball is filled with the *vitreous body*, a transparent, jelly-like material that has the characters of a primitive form of very watery connective tissue, showing widely scattered cells embedded in a matrix of gelatinous material in which appropriate reagents demonstrate a rich fibrillary network. Leucocytes are also found in it, especially where it is in contact with the retina. It has a very delicate envelope, the *hyaloid membrane* adherent to the retina at the optic disc and the ciliary region where arteries enter during fetal life. This membrane is thickened in front of the ora serrata by radial fibers that pass forward to the equatorial region of the lens capsule and are collectively termed the *zonula ciliaris*. This is composed of two layers, one of which lines the hyaloid fossa; the other, attached near the equator of the lens, is termed the *suspensory ligament*. The intervals behind this ligament and between the fibers are known as the *spatia zonularia*. Being easily inflated by a fine blowpipe, they then form a moniliform ring about the lens which was formerly known as the canal of Petit. The ligament completely encircles the lens, serves to hold it in position and to keep the capsule tense. In front the vitreous has a depression, the *hyaloid* or *patellar fossa*, into which the lens is received. The hyaloid membrane appears to be lost upon the zonula in front and not to be continued over the hyaloid fossa, the consistence of the vitreous at that place being maintained by a condensation of its substance. From the optic papilla forward there runs in fetal life a small vessel, the *hyaloid artery*, for the nourishment of the lens. This is represented in the adult by a central lymph space, the *hyaloid canal* (Fig. 2221). Just in front of the papilla this canal enlarges to a space known as the *area Martegiani*.

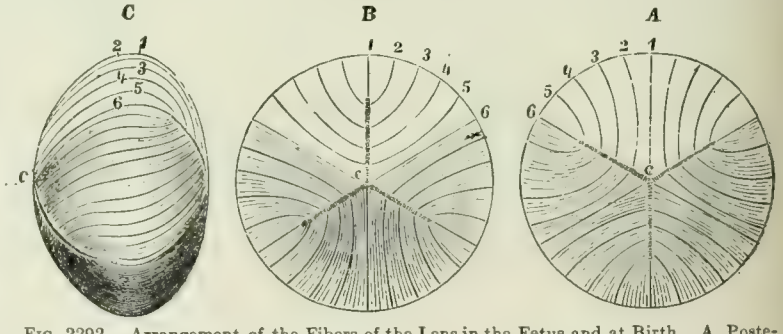


Fig. 2292.—Arrangement of the Fibers of the Lens in the Fetus and at Birth. A, Posterior surface; B, anterior surface; C, side; c, center of the lens stars, being the anterior and posterior poles of the lens; 1 to 6, course of fibers taken at equal distances.

The refractive index of the vitreous body is nearly that of distilled water, its weight is from 6.7 to 8.3 grams and its specific gravity is 1.005. Its reaction is alkaline, and the proportion of water found in it is very high, being 98.40 to 98.64 per cent.

FRANK BAKER.

Eye, Dioptrics of the.—The optic properties of the eye were not understood until Kepler, in 1602, evolved the theory of optical instruments in general. The importance of the various parts of the eye in refraction was further elucidated by the Jesuit Scheiner in 1619. Minor additions were successively brought out by the labor of different authors, but it was only after Gauss had published his mathematical investigation of the cardinal points ("Dioptrische Untersuchungen," Göttingen, 1841) that the complete theory of the refraction in the eye could be deduced. This was done successfully by Listing, in the article "Dioptrik des Auges" in Wagner's "Handwörterbuch der Physiologie" (1853), who, by a critical selection of the older measurements of the refractive indices of the eye by Chossat and by Brewster, of the anatomical measurements of dimensions and curvature by Kraus, Kohlrausch, and others, determined the position of the ocular cardinal points with considerable accuracy. The most marvellously accurate methods, however, for measurements of the living eye, were first introduced by Helmholtz, who, in his "Handbuch der physiologischen Optik" (1867; second edition, revised, 1896), has produced a masterly treatise of rare originality, which every student of the subject must consult in the original. Since the publication of his large work, the first part of which on refraction appeared in 1856, Helmholtz has pursued these studies with the aid of numerous students, most of whose articles have appeared in the *Archiv für Ophthalmologie*. In an article by Reich (*Arch. f. Ophth.*, 1874, vol. xx., 1), Helmholtz corrected some of his former measurements and figures, and accepted as more nearly representing the values of the cardinal points in the average eye the figures which we have reproduced in the text of this article. Extensive measurements, especially of the curvature of the cornea, were also made by Donders ("Anomalies of Accommodation and Refraction," 1864) and by Mauthner ("Vorlesungen ueber d. optischen Fehler des Auges," 1872), and later by Reuss (*Arch. f. Ophthalmologie*, xvii., 1, p. 27). The entire theory of the formation of images in the eye, including physiological optics in general, was most exhaustively treated in Aubert's "Grundzüge der phys. Optik," in vol. ii. of Graefe and Saemisch's "Handbuch der gesammten Augenheilkunde" (1876), while important additions were made in Nagel's "Anomalien der Refraction," in vol. vi. of the same work. Very complete is also the treatise of Fick in vol. iii. of Hermann's "Handbuch der Physiologie." An excellent compilation with many original measurements is Tscherning's "Physiological Optics," trans. by C. Weiland. All of these works must be consulted for the early literature of the subject. In the English language the most important of the older treatises is the work by Donders on "Anomalies of Accommodation and Refraction" (1864), which book marked quite an era in our knowledge of the physics of the different refractive conditions of the eye. In connection with this latter subject the work of Jaeger ("Einstellungen d. dioptrischen Apparats," 1861) must also be mentioned.

The mechanism of accommodation had been extensively discussed by former authors, by whom, however, no facts were brought forth beyond those taught by every-day observation. By some the accommodative changes were referred to the variations in the size of the pupil, while others even denied the existence of any accommodation. The most complete mathematical discussion was furnished by Th. Young in the "Philosophical Transactions" of 1801, in which it was shown by experiment and by deductions that the accommodation cannot depend on any changes except those in the form of the lens. The experimental proof that such changes do occur was furnished simultaneously and independently of each other by Cramer (in various publications in the Dutch language, between 1851 and 1855, and by Helmholtz (*Monatsberichte d. Berliner Academie*, February, 1853). The mode of action of the ciliary muscle was first explained by Helmholtz theoretically, and was later confirmed experimentally by Hensen and Voelkers, who likewise studied the innervation of the accommodative apparatus ("Experimentaluntersuchung über den Mechanismus der Accommodation," 1868, and *Archiv f. Ophthalmologie*, 1873, vol. xix.). Important measurements of the changes in the curvature of the lens during accommodation, and a mathematical inquiry into their efficiency were published by Knapp (*Archiv f. Ophth.*, 1860, vols. vi. and vii.). Various doubts raised concerning the Helmholtz theory of accommodation were satisfactorily answered by confirmatory researches published by C. Hess in von Graefe's *Archiv f. Ophthalmologie* in a series of articles from 1897 to 1901. Our knowledge of the range of accommodation in health and disease is due mainly to the researches of Donders ("Anomalies of Accommodation and Refraction"). An account of the work that has been done since 1904, together with a complete bibliography, will be found in the article by Hering on "Physiologische Optik," chapters 12 and 13, vol. iii. (second edition) of the Graefe-Saemisch "Handbuch der gesammten Augenheilkunde," 1911, and in the article by Hess on "Refraktion and Akkommodation," chapter 12, vol. viii. (third edition) of the same work, 1911.

On the innervation of the iris there exists an extensive literature, scattered throughout numerous physiological and ophthalmic serials. The older literature is exhaustively compiled in Budge's "Bewegungen der Iris," 1855. The present writer presented likewise a full review of the physiology of the iris in the Chicago *Journal of Nervous and Mental Diseases* (April and July, 1874), in which the complete literature up to that date can be found. Whatever of importance has been done since 1874 is explicitly referred to in the text.

REFRACTION.—1. The term refraction refers in physics to the deviation of a ray of light from its straight path on passing from one transparent medium into another of different nature. In physiological optics, however, this term is used with a special significance, denoting the relation of the focal length of the eye to the position of the retina. The eye has a normal, or emmetropic (from ἔμμετρος, according to measure, and ὤψ, eye), refraction, if images of distant objects are sharply defined on the retina; the refraction is myopic, or near-sighted, if distant objects form images in front of the retina; while hypermetropia is that refractive state in which images of distant objects can be sharply defined only behind the actual place of the retina. Any refractive state other than emmetropia is referred to in general as ametropia (from ἄμετρος, disproportionate, and ὤψ, eye).

The eye of all vertebrates is an optic instrument, the principle of which is illustrated by the photographer's camera obscura. By means of a convex lens, the rays of light coming from the different points of external objects are so reunited as to form inverted, but geometrically correct, images of those objects on a screen. The screen is the retina, while the convex lens is constituted by all the transparent media of the eyeball.

A correct knowledge of the optic properties of the eye is not possible without some familiarity with the laws of physical dioptrics. Hence we must begin with a résumé of the laws of the refraction of light. In

order to keep this article within the allotted space, we will not attempt to follow out the mathematical deduction of all the various formulæ of which we must make use. For the complete mathematical proof of all the statements the reader must consult some of the works mentioned in the bibliography, especially those of Helmholtz and Donders.

The paths of the rays of light entering the eye, and the influence of the different media upon them, can be deduced from the following optic principles:

2. *Law of Refraction.*—From every point of a luminous or illuminated object there proceed rays of light in all directions. Every ray pursues a straight course as long as it passes through a uniform medium. When a ray passes from one transparent medium into another of different optic properties, it is refracted or deflected from its straight path, except when its original direction is vertical to the surface of the second medium. The extent of deflection depends on a specific property of each medium, viz., its refractive power. The relation of the refractive power of any one medium to that of another is termed the refractive index, and is usually designated by the letter n. Air is taken as the standard of comparison, and its index of refraction is called 1. Compared with air the refractive index of water is 1.334; of crown glass, 1.533; of flint glass, 1.664. A medium having the greater refractive index is said—in a somewhat loose manner—to have a greater optic density than another rarer medium.

The extent to which a ray of light is deflected from its straight path by refraction depends on the angle at which it strikes the surface, as well as on the refractive indices of the media.

Let A, in Fig. 2293, be air, with the refractive index $=n$, and B be glass, with the index $=n'$, the two being separated by the surface $s\ s'$. A ray of light, having the direction $a\ c$ in the air, will be bent in the direction $c\ d$ on entering the glass. If we erect the normal $b\ c\ e$ vertical to the surface at the point c, the angle $a\ c\ b$ is the angle of incidence of the ray $a\ c$; the angle $e\ c\ d$ is the angle of refraction. The latter is here smaller

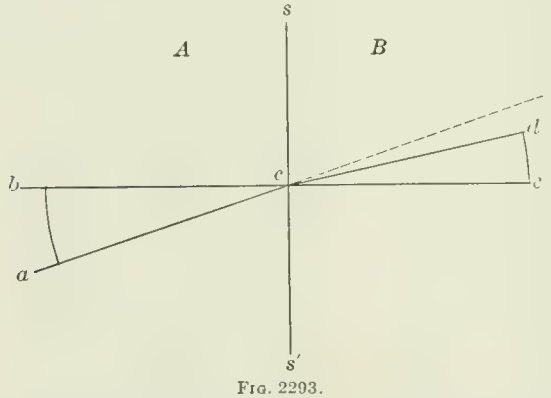


Fig. 2293.

than the former, for, in the denser medium, the refracted ray is bent toward the perpendicular. The relation of one angle to the other depends on the relation of the refractive indices of the two media, so that the sine of either angle is to the sine of the other inversely as the index of the corresponding medium is to that of the other, or

$$\frac{\text{sine } a\ c\ b}{\text{sine } e\ c\ d} = \frac{n'}{n} \qquad (1)$$

Since the sine of an angle zero is likewise zero in value, it follows that when the incident ray is itself perpendicular to the refracting surface, it continues to be perpendicular after its entrance into the second medium, *i.e.* it is not deflected at all from its course.

The path which a ray describes in passing through one or more refracting surfaces is the same, whether that ray travels forward or backward from any given point in its course.

3. If the denser medium is in the form of a plate bounded by parallel surfaces and surrounded by the same rarer medium on both sides, a ray, after passing through the plate, follows a direction parallel to its original course, but is displaced laterally.

For in Fig. 2294, where A represents the air, and B the plate of glass, the ray $a\ c$ on entering the glass is

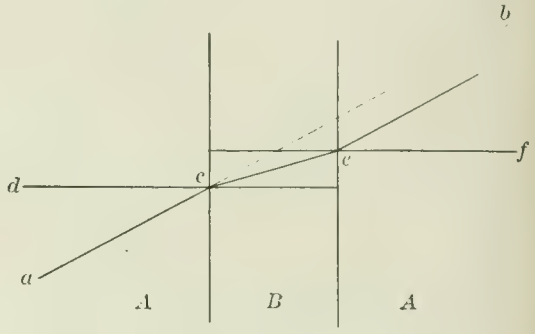


Fig. 2294.

bent toward the perpendicular $d\ c$ to an extent exactly counterbalanced by its deflection from the perpendicular $e\ f$ on leaving the glass. Hence the ray $e\ b$ after passing through the glass is parallel to the prolonged direction of the original ray $a\ c$.

4. *Refraction by a Single Refracting Surface.*—When the denser medium is bounded by a convex spherical surface, all rays (except one) coming from any point in the rarer medium are deflected in such a manner as to be less divergent after their refraction than they were before. The one ray not deflected is the one striking the surface vertically, hence coinciding in the radius or axis of that point of the surface. It is hence termed the *axial ray.*

In Fig. 2295 let a be a point in the air from which rays proceed toward the convex surface $b\ c$ separating the air from the glass. Let o be the center of curvature of the refracting surface $b\ c$. Let the ray $a\ c$ be vertical to the surface, *i.e.* coinciding with the direction of the radius $o\ e$; it will hence not be deflected from its course. The ray $a\ b$ is, however, refracted. If $o\ b$ is the radius of the surface, and is hence vertical to the point b, the angle of refraction $f\ b\ o$ can be found by the formula:

$$\text{sine } f\ b\ o : \text{sine } a\ b\ d = n : n'$$

It is evident from Fig. 2295, that if the point a be not too near to the refracting surface, the refracted ray

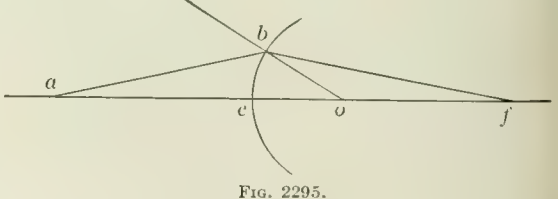


Fig. 2295.

$b\ f$ will verge toward the undeflected axial ray, and will meet it in some point which we will designate f. It can be shown by a mathematical analysis, not only that this one ray, but that all rays proceeding from the point a toward the convex surface $b\ c$ are so refracted as to meet the axial ray at the point f, provided we limit our analysis to those rays only which are not very oblique to the axis, and do not strike the surface far from the axis. With this provision, the point f is the collecting point of all rays coming from a; the point f is therefore the image of the point a.

If we trace, however, the course of the rays which are very oblique to the axial ray, or which strike the surface far from its axis, we shall find that they meet the axial ray at various points different from f. Such a want of exact reunion of all the rays, when too large an extent of the refracting surface is exposed, constitutes the fault of optic instruments known as *spherical aberration*. The refraction of such very oblique rays is represented, in a somewhat exaggerated manner, in Fig. 2296.

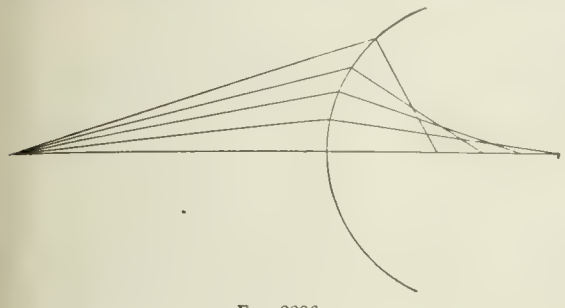


Fig. 2296.

5. *Focal Length.*—When the luminous point is situated in the rarer medium at a distance infinitely great compared with the dimensions of the refracting surface, the different rays emanating from that point strike the refracting surface with so little divergence as to be practically parallel to each other. These parallel rays are rendered convergent by their refraction. The point where these refracted rays meet is called the principal posterior focus, and its distance from the refracting surface is the posterior focal length. This distance, designated usually as F'', depends on the relative indices of refraction of the first and second media and on the radius of curvature of the refracting surface. If we call this radius r, the formula for the posterior focal length is:

$$F'' = \frac{n'\, r}{n' - n} \qquad (2)$$

The plane drawn through the posterior focus vertical to the axis of the refracting surface is called the posterior focal plane.

As the luminous point moves nearer to the refracting surface, so as to make the incident rays more and more divergent, their focal reunion recedes farther from the surface, until a certain point in front of the convex surface is reached, the rays proceeding from which are so divergent that they can no longer be rendered convergent by their refraction, but only parallel. Their point of focal reunion may then be considered as infinitely far behind the surface. The point in front of the surface from which these rays proceed is the principal anterior focus, and its distance from the surface, which we will call F', is the anterior focal length. A vertical plane laid through it is the anterior focal plane. F' can be found by the formula:

$$F' = \frac{n\, r}{n' - n} \qquad (2a)$$

A comparison of formulæ (2) and (2a) shows that the anterior and posterior focal lengths are not alike under the circumstances, but that

$$F' : F'' = n : n' \qquad (2b)$$

Remembering that the path of the rays is the same, whether they travel forward or backward, we may also define the anterior focus as the point in which those rays unite which proceed parallel to each other in the denser medium toward the refracting surface.

6. The distance of the focal reunion from the refracting surface can be calculated for any set of rays, coming from any point, if we know the distance of that point from the surface, and also the anterior and posterior focal lengths of the refracting surface. If the known distance of the luminous point is l, that of the corresponding focal reunion f'' will be:

$$f'' = \frac{F''\, f'}{f' - F'} \qquad (3)$$

Conversely, the distance of a luminous point f can be found, if we know the distance of the corresponding focal reunion or image f'', according to the formula

$$f' = \frac{F'\, f''}{f'' - F''} \qquad (3a)$$

A very convenient formula for finding the place of the focal reunion of rays coming from a point at a known distance can be obtained by the transformation of (3) and (3a). If we designate the distance from the luminous point to the anterior focus, viz., $f' - F'$ as l' (counting l' negative if f' is nearer to the surface than F'), and the distance from the posterior focus to the point of focal reunion of the rays in question, viz., $f'' - F''$ as l'', then

$$l'\, l'' = F'\, F'' \qquad (4)$$

In all these instances the relation of luminous point and corresponding image can be reversed without change of position; in other words, if the point x is the image of the point a, then for rays proceeding in the reverse direction, a is also the image of the point x. Any two points having such a relation of luminous point and corresponding image are called *conjugate points*.

7. *Virtual Image.*—When the rays, coming from a point nearer than the anterior focus, strike the refracting surface, their divergence is too great to be entirely overcome by the refraction. They cannot therefore be united to form an actual image; but if their direction, after the refraction, be prolonged backward, their prolongations meet to form a *virtual* image. The focal reunion of such rays is therefore negative.

Thus, in Fig. 2297, if F' be the principal anterior focus of the refracting surface $s\,s'$, and f' the luminous

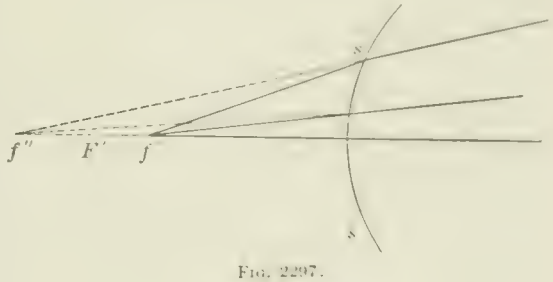


Fig. 2297.

point, the rays proceeding from f' will have a divergence after their refraction, as if they came from the point f'', which is therefore the image of f'. Since f'' is on the same side of the surface as f', its distance is counted negative. It can be determined by formula (3a) or (3b).

8. *Formation of Images.*—Since an object is made up of an infinitely great number of points, and since of every such point in front of the refracting surface an image is formed somewhere behind the surface, therefore an image must also be formed of the entire object. From every point of the object there proceeds one ray, which is not bent from its course by refraction, viz., the ray which strikes the surface perpendicularly, and hence coincides in direction with the radius of the point of the surface. Such rays are termed *rays of direction*. Since all other rays proceeding from any one point of the object meet the ray of direction at the corresponding distance of focal reunion, the image of every point of the object is situated somewhere in the path of the ray of direction coming from that point. Since every ray of direction coincides with

one of the radii of the refracting surface, the rays of direction must, therefore, like the radii, intersect at the center of curvature of the surface. Since the focal length of a refracting surface is always greater than its radius, according to formulæ (2) to (3a), therefore the actual images of objects farther off than the anterior focus are formed somewhere beyond the point of intersection of the rays of direction, and are hence inverted. This is illustrated by Fig. 2298.

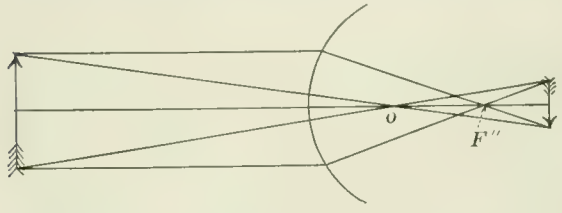


Fig. 2298.

The point where the rays of direction cross, viz., the center of curvature of the surface, is also called the *optic center*.

9. When the object lies in a plane vertical to the axis of the refracting surface, all points of the object near the axis are sensibly at the same distance from the refracting surface, as measured by the length of the rays of direction. Their images are therefore likewise situated at equal distances behind the surface, and hence lie in a plane vertical to the axis. But this is true only as long as the angle included between the ray of direction coming from that point of the object and the axis of the refracting surface is so small as to permit the substitution of its chord for its arc without practical error. In the case of objects of dimensions exceeding this limit, the images lie in a curved line, with the concavity toward the refracting surface, as shown in Fig. 2299.

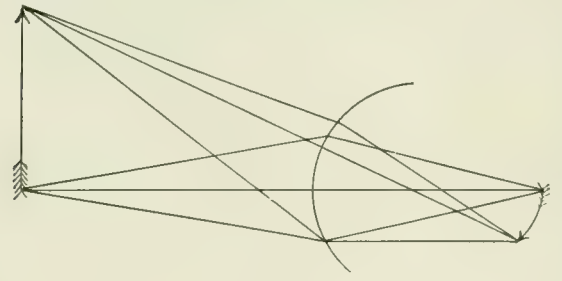


Fig. 2299.

Such extensive images are blurred, on account of spherical aberration. (See Section 4.)

10. *Circles of Diffusion.*—An image is sharply defined only in the plane of focal reunion of the rays. In any plane anterior to this the rays are not yet united; in any plane posterior to this the rays diverge again. Hence a screen placed in front or in the rear of the focal reunion receives a blurred image, since every point of the object is represented—not by a single point—but by a circle of diffusion. The size of the circles of diffusion increases with the distance of the screen from the point of focal reunion in either direction, and with the extent of the refracting surface through which rays pass. This is evident from Fig. 2300.

11. *Size of Images.*—The size of the image is to the size of the object as the distance of the image from the optic center is to the distance of the object from the same point. If we designate, in Fig. 2301, the distance of the object $A\ B$ from o, the optic center, as g', and the distance of the image $a\ b$ from o as g'', we can express the relation of size by the formula:

$$a\ b : A\ B = g'' : g' \qquad (4)$$

the truth of which is evident from the similarity of the two triangles $A\ B\ o$ and $a\ b\ o$. For certain calculations the relation of size can be more conveniently stated as

$$a\ b : A\ B = f'' - F'' : F'' \qquad (4a)$$

in which formula F'' is the principal posterior focal length, and f'' the distance of the image from the surface. The derivation of this formula is shown in Fig. 2302.

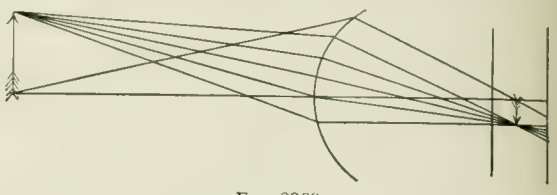


Fig. 2300.

For if we draw in this figure the ray $A\ d$ from the point A parallel to the axis, it is refracted as if it were a ray coming from some point in the axis at an infinite distance, that is to say, it is deflected to F'' the posterior focus, and proceeds beyond F'' until it meets the other rays coming from A in the point of focal reunion a. Thereby are formed the two similar triangles $d\ c\ F''$ and $a\ b\ F''$. Hence,

$$a\ b : d\ c = f''\ F'' : c\ F''$$

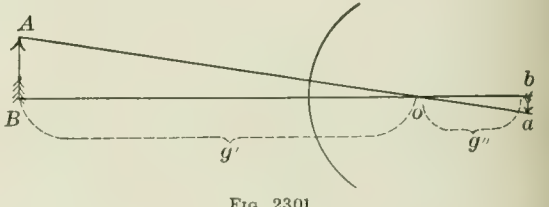


Fig. 2301.

Since the line $A\ d$ has been drawn parallel to $B\ c$, the side $d\ c$ is equal in size to the object $A\ B$. If we substitute the term F'' for the line $c\ F''$, and the term $f'' - F''$ for the line $f''\ F''$ according to our premises we get the equation:

$$a\ b : A\ B = f'' : F''$$

12. *Virtual Images.*—When the object is nearer to the refracting surface than the principal anterior focus, there is no real image, but only a virtual image is formed on the same side of the surface as the object is itself. In this case f'' is hence negative, otherwise the same formulæ apply as above. Since the rays of direction do not cross, this virtual image is erect, and

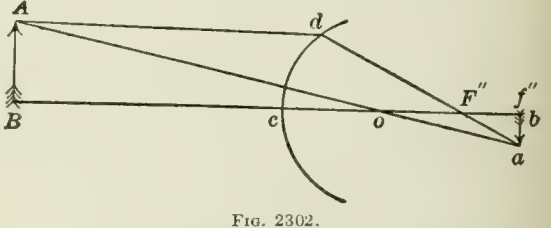


Fig. 2302.

since it is always farther from the optic center than the object, it is larger than the object. The amplification of the image diminishes as the object approaches the refracting surface, for when the object has just passed through the anterior focus the image is at an infinitely great distance, and is therefore most enlarged, while when the object touches the refracting surface, object and image coincide in position and size. The formation of virtual images is shown in Fig. 2303.

13. All the facts above stated with reference to images formed in the denser medium of objects situated in front of the refracting surface, are equally true conversely of images formed in the rarer medium of objects situated behind the refracting surface.

14. *Refraction by Concave Surfaces.*—When the refracting surface is concave on the side of the rarer medium, rays coming from any one point are not reunited in an actual focus. But if the direction which they assume after their refraction be prolonged backward, the prolonged rays will meet in a point

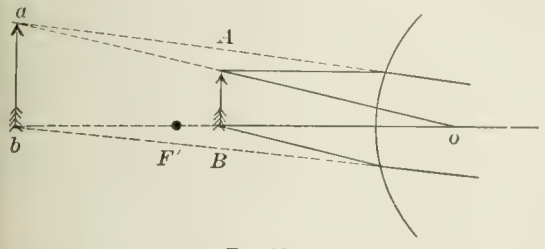


Fig. 2303.

representing the focus. This focal length is therefore always negative, that is to say, the focus is always on the same side of the surface as the object itself. The position of the principal foci or any conjugate point of focal reunion can be found by the same formulæ as in the case of a convex surface, but these values are always negative, because the radius of curvature of the concave surface is negative in direction. The images formed by a concave refracting surface are hence always on the same side as the object, that is to say, they are not real, but virtual, and can only be smaller than the object, as shown in Fig. 2304.

15. *Refraction by Successive Surfaces.*—When light passes through a number of surfaces of different media, the above-developed formulæ apply to the refraction through each surface. Thus the focus of the first surface forms the luminous point for the second refraction, its distance being counted positive when it is in front of the second surface, and negative when it happens to be behind that surface. Similarly the image formed by the second surface is the object for the third surface, and so on. But such calculations become very cumbersome if we try to follow actually the course of the rays through their successive refractions. The matter is simplified by treating the series

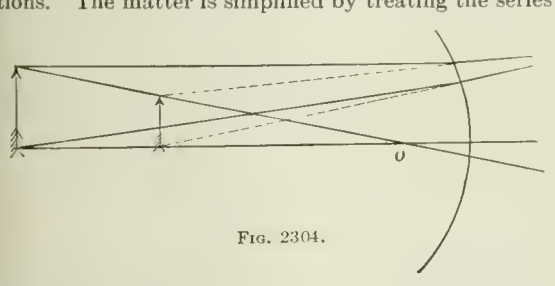


Fig. 2304.

of surfaces as one system having certain fixed points, the position of which determines the path of all rays. These are called the cardinal points. Their position remains constant in any given system, and can be calculated, if the refractive indices of the media, the radii of curvature of all the surfaces, and the distances of all the surfaces from each other are known, provided the centers of curvature of all the surfaces lie in a straight line, the axis of the system. If the latter condition is fulfilled, the system is said to be centered. The cardinal points are the two foci, the two principal points and the two nodal points.

16. *The Foci.*—The foci, anterior or first, and posterior or second, are the two points—one on either side of the system—at such distances that rays coming from the focus are rendered parallel to each other by their last refraction. Conversely parallel rays entering the system from either side, are united in a point in the focus on the other side, as has been shown to occur in the case of a single refracting surface. The distance of either one of the foci of a compound system from the surface next to it may be computed in the following manner: Let n be the refractive index of the first medium, n_1 of the second, n_2 of the third, and so on. Let S_1 be the first refracting surface, and r_1 its radius of curvature; S_2 the second surface, and r_2 its radius, and so on. The value of r is positive if the surface is convex on the side of the luminous point; negative if it is concave. Let d_1 be the distance from the first surface to the second, d_2 from the second to the third, and so on. Determine the foci of each surface by itself, without reference to the other surfaces. According to formulæ 2 and 2a, we get for the first surface,

$$F_1' = \frac{nr_1}{n_1 - n} \text{ and } F_1'' = \frac{n_1 r_1}{n_1 - n}$$

and for the second surface,

$$F_2' = \frac{n_1 r_2}{n_2 - n_1} \text{ and } F_2'' = \frac{n_2 r_2}{n_2 - n_1}$$

The posterior focus for the first and second surfaces taken together will now be found by considering F_1'' as the luminous point for S_2; and, on applying the formula (3),

viz., $f'' = \frac{F''' f'}{f' - F'}$ we get the equation:

$$F_{(1+2)}'' = \frac{F_2''(d' - F_1'')}{(d' - F_1'') - F_2'} \qquad 3b$$

which states the distance of the posterior focus of the system of surfaces S_1 and S_2 from S_2. The distance of the anterior focus of S_1 and S_2 together, from S_1, is similarly found by the application of formula (3a), viz., $f' = \frac{F' f''}{f - F''}$ and following the light in the reverse direction, hence

$$F_{(1+2)}' = \frac{F_1'(d_1 - F_2')}{(d_1 - F_2') - F_1''} \qquad 3a$$

By treating the surfaces S_1 and S_2 as one system, we can then proceed to determine the foci for $S_{(1+2)}$ and S_3, and so on.

The foci of an optic system having been determined, the focal length is now measured by the distance of each focus from its corresponding principal point. If we call the anterior or first principal point H', and the posterior or second principal point H'', then $F'\ H'$ is the anterior focal length, and $H''\ F''$ is the posterior focal length.

17. *The Principal Points.*—The principal points are the two points where the axis of the system is cut by the two principal planes. The significance of the

Fig. 2305.

principal planes can be best explained on comparing the refraction by a single surface with the course of rays through a compound system. In the case of the single surface $a\ b$, Fig. 2305, the ray $F''\ a$ coming from the anterior focus, is, by its refraction, made parallel to the axial ray $F'\ F'''$. Incident and refracted rays intersect here in the plane of the refracting surface. The same is true of the ray $F''\ b$ coming from

the posterior focus, and its continuation, *b c*, after refraction. In Fig. 2306, however, where there are two refracting surfaces, *a b* and *a′ b′*, the ray, *F″ a*, coming from the anterior focus, is twice bent from its course, viz., at each surface, so as finally to assume the direction *a′ d*, parallel to the axial ray. In this case the incident ray, *F″ a*, and the refracted ray, *a′ d*, do not intersect, being separated by the space between *a* and *a′*; but if we prolong them through this space, their prolongations intersect at the point *h′*. A plane, *h′ H′*, laid through this point, vertical to the axis, is the first principal plane. Similarly, if we prolong the ray *F″ b′*, which proceeds from the posterior focus to the surface *a′ b′*, it will cut the backward prolongation of the refracted ray *b c* at the point *h″*, which point

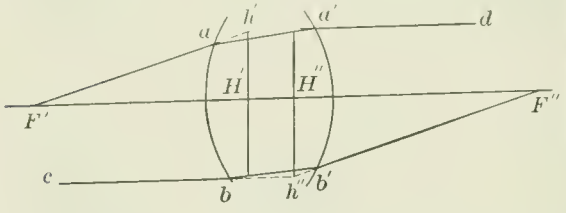


Fig. 2306.

determines the position of the second principal plane. It is evident, from Fig. 2306, that the ray which before entering the system is directed toward the point *h′* in the first principal plane, has a direction after its last refraction as if it came from a point in the second principal plane at the same distance from the axis as the point *h′*. Likewise the ray which proceeds in the opposite direction from *F″* toward the point *h″* has a direction, after its last refraction, as if it came from a point in the first principal plane at the same distance from the axis as the point *h″*. This mutual relation of the two principal planes is the same for all rays, not merely those coming from *F′* or *F″*; and it is true also for any distance at which the points *h′* and *h″* may be from the axis within the limitations of Section 4. In other words, any ray which is directed toward a given point in the principal plane on the side from which it comes, apparently emerges from the other principal plane at the same distance from the axis. We can thus determine by construction the direction of any ray after its refraction through a compound system, and thereby find the places of the image formed by such rays, if we know the position of the foci and the two principal planes. In Fig. 2307, let *a a′* be the first, and *X X′* be the last refracting surface of a compound system; let *H′* be the first,

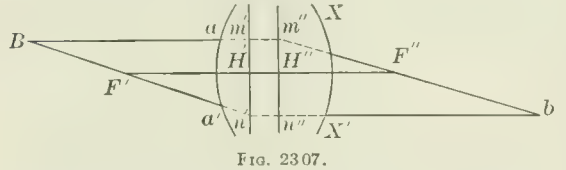


Fig. 2307.

and *H″* be the second principal point, *F′* the anterior, and *F″* the posterior focus. Draw the axis *F′ F″*. From the point *B* there proceeds the ray *B a*, parallel to the axis, and verging toward the point *m′* in the first principal plane. Hence, after its last refraction, that ray has a direction as if it came from the point *m″* in the second principal plane, going through the posterior focus *F″*. Another ray convenient to follow is the one coming from *B* and passing through *F′*. This verges toward the point *n′* in the first principal plane. Hence, by its refraction, it is turned in the direction *n″ b*, as if coming from *n″* and proceeding parallel to the axis. Where the two refracted rays meet, at the point *b*, is the image of the luminous point *B*.

Since the course of rays is determined by their relation to these imaginary principal planes, the focal lengths of a system must be measured by the distance of each focus from its corresponding principal point, and not by the distance of the foci from the refracting surfaces. Indeed, for all subsequent purposes, we can practically ignore the position of the refracting surfaces of any system, after we have once determined the position of the foci and of the principal planes. For now all the problems relative to the position of object and image can be solved by the same formulæ as in the case of a single refracting surface, by measuring the focal lengths from the principal planes.

18. The position of the two principal points is determined by the position of the two planes in which the images of a certain other plane are of equal size and direction. In every refracting system there exist only two such planes, and these are the principal planes; and there exists, moreover, only one plane of which two images of equal size and direction are possible. Hence, in order to find the principal points, we must determine where a line must be in order to form two images of the same size and direction, and then learn the place of these two images.

This proposition can be demonstrated by means of Fig. 2308, in which we have a refracting system bounded by the surfaces *s′ S′* and *s″ S″*. *F′* is the first and

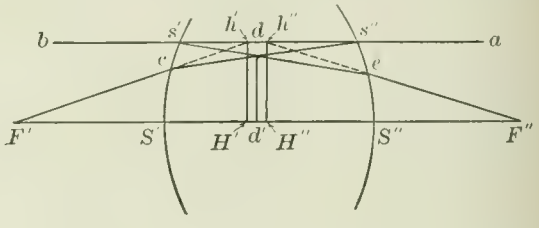


Fig. 2308.

F″ the second focus. Draw the ray *F′ c*, which is deflected toward *s″* by the surface *s′ S′*, and is made parallel to the axis by the surface *s″ S″*. By the intersection of the prolonged incident and refracted rays the point *h′* determines the position of the first principal plane. Similarly a reverse ray going from *F″* to *e* is bent twice, so as to follow ultimately the direction *s′ b* parallel to the axis. The prolongations of the ray before entering and after leaving the system give us the point *h″*, and thereby the position of the second principal plane. If we draw a line *d d′* vertical to the axis from the point *d*, where the rays coming from each side intersect after their first refraction, the virtual image of *d d′* produced by the surface *s′ S′* coincides with the first principal plane *h′ H′*, while the image formed by the surface *s″ S″* coincides with the second principal plane *h″ H″*, as is evident from the refraction of the rays according to the construction; and these two images are alike in size. The distance of *d′* from each surface is determined by the equation (4a).

$$a\ b\ (image) : A\ B\ (object) = f'' - F'' : F''$$

or more conveniently, on account of the erect position of the virtual image,

$$a\ b : A\ B = F'' - f'' : F''$$

Each surface is here considered independently of the other. Hence it can be deduced that the distances of *d′* from each surface must be to each other as the focal lengths of the surfaces, in order to have the images formed by the two surfaces of equal size. This is shown in Fig. 2309, where *P′ S″* is the focal length of the surface *s″ S″* in the medium between the two surfaces and *P″ S′* of the surface *s′ S′*.

A consideration of the two triangles *P′ S″ s″* and

$P''\ S'\ s'$ and their segmentation by the line $d\ d'$ proves that

$$d'\ S' : d'\ S'' = P''\ S' : P''\ S'' \qquad (6)$$

Hence, in order to find the principal planes of a system, determine the position of a point in the axis, the distances of which from the two refracting surfaces are to each other as the focal lengths of these surfaces in the medium between them. Then calculate the place of the images of this point formed by each surface independently of the other, according to formula (3).

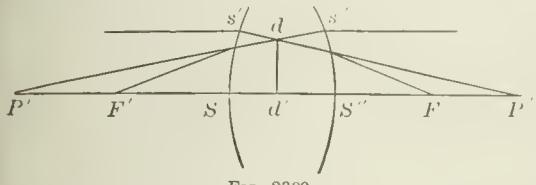


Fig. 2309.

When the optic system consists of more than two refracting surfaces, determine the principal points for two adjoining surfaces, and then divide the distance between the one principal point next to the third surface and the third surface into two parts, which are to each other as the corresponding focal lengths in the intervening medium. The images of the dividing point formed independently by the third surface, and by the system of the other two surfaces, are then the principal points of the system of three surfaces.

19. *The Nodal Points.*—The nodal points of a compound system replace the optic center of a single refracting surface. For while all rays of direction pass undeflected through the optic center of a single surface, a second surface will deflect all rays with the exception only of the axial ray. Hence a single optic center cannot exist in a compound system. But there exist two points in the axis, viz., the nodal points, of such properties that a ray directed toward the first before entering the system pursues a course after its final refraction as if it had passed through the second nodal point parallel to its original direction.

That a pair of points of such properties must exist in any compound system is evident from Fig. 2310, where F' is the first and F'' the second focus, and $m'\ H'\ n'$ the first and $m''\ H''\ n''$ the second principal plane. A ray

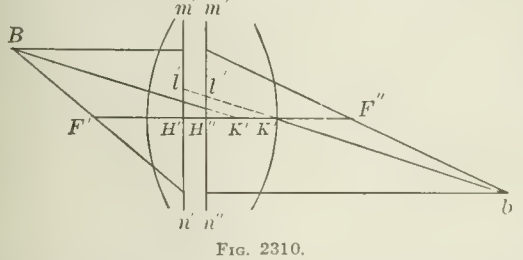


Fig. 2310.

$B\ m'$, coming from the luminous points B, forms with the refracted ray $m''\ b$ any angle of less than 180° as seen from below, while the ray $B\ n'$ forms with its refracted prolongation $n''\ b$ an angle greater than 180° as seen from below. Somewhere between m' and n' there must be a level where the incident ray includes with its continuation beyond the second principal plane an angle of 180° exactly, in other words, where the two are parallel. Let this be at the level l'. If we prolong the incident ray $B\ l'$, the points where this prolonged ray and the refracted ray $l''\ b$ cut the axis, viz., K' and K'', answer the requirements of the nodal points. The position of the nodal points relative to the principal points is made evident in Fig. 2311.

In this figure we will draw the line $B\ F''$ on F' vertical to the axis. From the point B there proceeds a ray of direction $B\ K'$ to the first nodal point K'. According to our premises the ray $K''\ b$ must be parallel to $B\ K'$ and in the direction $K''\ b$, the image of B, at an infinite distance from the entire system. Since the point B lies in the anterior focal plane, every ray proceeding from it is rendered parallel by its refraction to the ray of direction $B\ K'$ from B. Hence the ray $B\ K'$ parallel to the axis continued after passing through the second principal

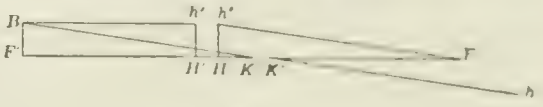


Fig. 2311.

plane, as $h''\ F''$ parallel to $K''\ b$, and hence also to $B\ K$. From the similarity of the triangle $B\ F'\ K'$ and $h''\ H''\ F''$ it is evident that the distance

$$F'\ K' = H''\ F'' \qquad (7)$$

and by reversing the figure and constructing the course of rays coming from the posterior focal plane, we can similarly learn that the distance

$$F''\ K'' = H'\ F' \qquad (7a)$$

and that hence

$$H'\ H'' = K'\ K'' \qquad (7b)$$

which latter corollary is also apparent from Fig. 2310. The position of the nodal points can hence be at once learned by formulæ (7) and (7a), after knowing the position of the principal points and of the foci. And thus we have all data necessary to follow the course of rays through any compound optic system.

20. *Lenses.*—It will be best to refer briefly to the optic properties of glass lenses before we proceed to the eye itself. According to the curvature of their surfaces and the distance between them, lenses either reunite into one point all the rays coming from one point, or disperse them. The former, or collecting lenses, have a positive local length. They form inverted actual images of distant objects, and erect, virtual, and enlarged images of objects nearer than their focus. The latter, or diverging lenses, have a negative focal length, and can form only erect, virtual images, smaller than their object. When both surfaces of a lens are convex, or one is convex and the other plane, the lens belongs to the former variety; when one surface is concave and the other plane, or when both are concave, we have a diverging lens with negative focus. When one surface is convex and the other concave, the positive or negative value of the resulting focal length depends not only on the curvature of the two surfaces, but also on the distance between them.

The refractive index of the glass used for spectacles is so near 1.5 that we can calculate on that basis without important error, at least for spectacles. Taking this index we find that in a plano-concave, or plano-convex lens, the focal length is twice the length of the radius of the curved surface, measuring from the curved surface, according to formula (2) or (2a). The first and second focal lengths are of course equal to each other, when the lens is surrounded by the same medium on both sides, according to [illegible]. The distance of the foci from the plane surface is, however, not the same as from the curved surface, for the focal lengths are measured from the principal points, one of which coincides with the curved surface, while the other is between the two surfaces. But for most of our purposes we can ignore the thickness of the glass lenses, as long as this is slight compared with the other dimensions, and practically measure the focal length from the surface, or, indifferently, from the center of the lens. If, hence, we express the focal length of a plano-convex lens as

$$F = [illegible]\ r$$

we get for a biconvex lens the formula

$$F = \frac{r' + r_2}{2}$$

If the radii of curvature of the two surfaces are alike, we find the focal length equal to the radius, provided the index of refraction is practically 1.5. This applies similarly to biconcave lenses, F being, however, negative. In lenses with one convex and one concave surface, the measurement of the focal length is not quite so simple, because the thickness of such a lens cannot be ignored without error, and the principal points can in such a combination be outside of the substance of the lens.

The so-called strength of lenses is measured differently, according to the unit which we adopt. Formerly a lens of the local length of one inch—either negative or positive—was taken as the standard and called 1. Any lens of longer focal distance could be named only in fractions, $\frac{1}{2}$ being one-half of that strength; that is to say, having a focal distance of two inches, and $\frac{1}{12}$ having twelve inches focal length, while a stronger lens, greater than 1, had a corresponding shorter focal distance. Since the adoption of the metric system in ophthalmology, the opposite way of enumeration has been employed. A lens of the focal length of 1 meter is now taken as unit, and called one dioptric, or 1 D. Any lens of longer focal length is expressed in a decimal fraction, thus, 0.25 D means a lens of 4 meters focal length. The stronger lenses, on the other hand, are measured by several dioptrics; thus, 10 D, being a lens of $\frac{1}{10}$ meter, or 10 c.c. focal length. Only the latter system is now in use. As regards the convenience in calculation, for which purpose the dioptric system was introduced, there is really not much difference between them. In order to convert the number of a lens from one system into another, it is to be remembered that the meter is equal to 39.37 English inches, or 36.94 French inches. On account of inaccuracies in grinding glasses, the whole numbers, 40 (English), and 36 (French), are close enough for practical purposes. Hence, to get the dioptric equivalent of an English number, divide that number into 40, and to translate a certain number of dioptrics into the French inch system, divide the number into 36.

21. In order to examine the refraction in the eye we must determine the refractive indices of the different media, the curvature of the surfaces, and the distances between the separate surfaces.

22. *Refractive Indices of the Media of the Eye.*—The refractive indices have been measured by various observers in dead eyes by means of different physical methods. On account of less perfect methods former results must be taken with some caution. Even the more recent determinations made with Abbé's refractometer have yielded not inconsiderable discrepancies among different observers, which may perhaps be attributed to individual variations. The table of refractive indices, given below, is copied from Zehender and Matthieson. It is the most complete of all recent determinations.

The indices of cornea, aqueous humor, and vitreous body are so nearly alike that an average index of the three can be used as a basis for calculation without appreciable error. Helmholtz assumes 1.3365 as the most nearly correct average in his latest publication. While the index of the capsule of the lens is considerably above this figure, this membrane is so thin and its surfaces are so nearly parallel to each other that its influence on the rays can be neglected without error. The index of the lens itself increases from the external layer to the nucleus, so that the lens really consists of a large number of layers of increasing optic density. By reason of this stratified arrangement the total refractive power of the lens is greater than it would be were the entire lens of the refractive index of its nucleus. For each layer, as we proceed toward the nucleus, increases not only in refractive index but also in convexity. This is evident when we compare the following two lenses, the thickness of which must not be more than a small fraction of the focal length. Let one of these lenses, A, be homogeneous and have the refractive index n'', the index of the surrounding medium being n, while the other lens, B, has only a core or nucleus more convex than the surface of the lens of the index n'', the superficial layer having an index n', intermediate between n and n''. If n' is now very nearly equal to n, we have practically a lens of the same index as that of the lens A, but of shorter radius of curvature, and hence of shorter focal length. If n', however, is very nearly equal to n'', the lens B will be practically of the same strength as the lens A, but never less. Hence, no matter in what ratio the index increases as we proceed toward the nucleus, the lens gains thereby in strength. The special advantages of this stratification over a homogeneous lens is the more regular refraction of rays very oblique to the axis, as has been shown mathematically by Hermann. Thereby the images of objects situated laterally from the axis of the eye are not distorted as they would be when projected by a glass lens. The actual refraction of the excised human lens was found by Helmholtz in two measurements to be equal to that of a homogeneous lens of the same curvature, but with a refractive index = 1.4519 and 1.4414. But in a later estimate he adopted 1.4371 as the more nearly correct average total refractive index of the lens in its normal attachment during life.

Table of Refractive Indices (Zehender and Matthieson).

Subject.	Cornea.	Aqueous humor.	Anterior capsule of lens.	Lens.			Posterior capsule of lens.	Vitreous body.	Distilled water.
				Cortical layer.	Middle layer.	Nucleus.			
Male, 50 years, I.				1.3953	1.4087	1.4121	1.3455		
Male, 50 years, II.	1.3770			1.3853	1.4067		1.3658	1.3348	
Female, 45 years, I.					1.4044	1.4112			
Female, 45 years, II.					1.4044	1.4094			
Female, 26 years, I.			1.3600	1.3867	1.4056	1.4154			
Male, I.	1.3772			1.3902	1.4062	1.4077		1.3342	
Unknown, I.					1.4076	1.4091			
Unknown, II.						1.4096			
Female, 45 years, I.				1.3930	1.4018	1.4101			
Female, 45 years, II.				1.3811	1.4073	1.4107			
Child of two days, I.	1.3721	1.3338	1.3821				1.3503	1.3340	
Child of two days, II.			1.3780				1.3572		
Average	1.3754	1.3338	1.3734	1.3886	1.4059	1.4106	1.3547	1.3343	1.3326

23. *Curvature of the Ocular Surfaces.*—The curvature of the surfaces cannot be measured with accuracy in the dead eye, on account of the altered tension of the eyeball. In the living eye the curvature can be calculated from a measurement of the size of images reflected from the surfaces. The cornea, for instance, acts as a polished convex mirror, producing diminutive images, apparently behind its surface. The size of such an image is to half the radius of curvature of the mirror as the size of the object is to the distance of the object from the cornea. The size of the image is most conveniently measured by means of Helmholtz's ophthalmometer. This consists of a telescope, in front of which there is a thick plate of glass with parallel surfaces, which has been cut in two, so that the line separating its two halves exactly bisects the field of the telescope. The two plates can be turned on an axis vertical to the line of separation. As long as the two plates are practically one, that is to say, lie in one and the same plane, objects are seen through them in their natural shape; but when the two plates are turned in opposite directions, the objects appear split into two halves, which are displaced laterally in opposite directions, in proportion to the rotation of the plates. The explanation of this displacement has been given in Section 3. For actual use the ophthalmometer is directed toward the observed eye, at a distance of several meters, and the images of two lights, one placed on either side of the telescope, or rather, the ideal line uniting the two lights, are observed as reflected from the cornea. The two lights are, of course, placed in the prolongation of the line separating the two glass plates of the instrument. These plates are then turned by a screw until the image is doubled; that is to say, until the two halves are displaced laterally through the open space occupied by the image. From the observed degree of rotation, and the thickness of the plates, the extent of displacement, and hence the size of the image, can be calculated, and thereby the radius of curvature of the cornea be determined.

The radius of curvature, measured by reflection from the middle portion of the cornea, has been found to vary in different eyes from 7 to 8.2 mm., an average near 7.6 mm. being the most common. No definite relation has been found between this radius and any existing ametropia. On observing the reflection from the marginal portion of the cornea, it can be seen, even with the unaided eye, that the images are larger than in the center; that is to say, that the convexity of the cornea diminishes from the center toward the periphery. The cornea is therefore a segment of a sphere only in its central area, while toward the periphery its shape approaches that of an ellipse, the major and minor axes of which are to each other in the ratio of about 9 to 10 or 11. The posterior surface of the cornea is found in the dead eye to be nearly concentric with the anterior surface, This fact, in connection with the rather slight difference in the indices of cornea and aqueous humor, allows us to regard the cornea, aqueous humor, and vitreous body as one optically homogeneous medium, bounded by a single surface.

The radius of curvature of the anterior surface of the lens has been found to vary between 9 and 12, and exceptionally even 14 mm., averaging about 10 mm.; and that of the posterior surface between 5.5 and 6.5. The images reflected from these surfaces are so faint, on account of the small difference in the refractive indices of aqueous humor and lens, that the ophthalmometer can be used to advantage only with sunlight. The apparent size of these images requires a correction, for the cornea and aqueous humor act as a magnifying lens, interposed both in the path of the rays from the object to the reflecting surface, and, again, between the latter and the ophthalmometer. In the case of the images reflected from the posterior surface of the lens, the substance of the lens must also be taken [illegible] as part of the magnifying [illegible] hence to know the di[illegible] anterior surface, and from the latter to the [illegible] surface of the lens in order to calculate the radius of curvature. The posterior surface of the lens acts as a concave mirror, giving an inverted [illegible] small image.

24. *Distance between the Principal Points.*—The distance of the anterior surface of the [illegible] cornea has been determined according to various methods by Helmholtz and his pupils. By means of a focussing microscope with [illegible], or by means of the ophthalmometer with the aid of movable lights, it was learned how far the rim of the iris appears behind the cornea and the true position of the pupil was then calculated from the known refractive power of cornea and aqueous humor. Values between 3.2 and 4 mm. have been found in different eyes. Helmholtz adopted 3.6 mm. as a sufficiently accurate average to use in his diagrammatic eye. The distance of the posterior surface of the lens from the cornea can be measured only by complicated methods based on the observation of the parallax between the reflection from the cornea and that from the posterior surface of the lens, and by taking into account the influence of cornea, aqueous humor, and lens substance on the rays. It has been found to approximate very closely to 7.2 mm., which gives 3.6 mm. as the average thickness of the lens (while the eye is not accommodating). The lens taken out of the eye increases in thickness on account of elastic retraction, as will be explained in the section on Accommodation.

25. *Diagrammatic Eye.*—We learn thus that there are noticeable differences in the optic constants of normal eyes, so that two eyes, both emmetropic, are not necessarily identical in construction. But within the latitude of emmetropic eyes the deviations of the different figures from the average counterbalance each other, so that the object, the formation of sharp images of distant objects in the plane of the retina, is equally attained in all. From numerous measurements made by himself and others, Helmholtz has constructed the following diagrammatic eye, corresponding to the average figures of human emmetropic eyes:

	Millimeters
Refractive index of cornea, aqueous and vitreous humor	1.3365
Refractive index of the lens as a whole	1.4371
Radius of curvature of the cornea	7.829
Radius of curvature of the anterior surface of the lens	10
Radius of curvature of the posterior surface of the lens	6
Distance from the anterior surface of the cornea to the lens	3.6
Thickness of the lens	3.6

From these data are computed:

Anterior focal length of the cornea, aqueous, and vitreous humor	23.266
Posterior focal length of the cornea, aqueous, and vitreous humor	31.095
Focal length of the lens (in place)	38.571
Distance of first principal point of the lens from its anterior surface	1.351
Distance of second principal point of the lens from its posterior surface	1.774
Distance of the first principal point H' of the entire eye behind the cornea	1.779
Distance of the second principal point H'' of the entire eye behind the cornea	1.915
Distance of the first nodal point K' of the entire eye behind the cornea	6.986
Distance of the second nodal point K'' of the entire eye behind the cornea	7.331
Anterior focal length of the entire eye	15.568
Posterior focal length of the entire eye	20.719

This latter figure plus the distance of H'' from the cornea gives us 22.834 mm. as the optic axis from the anterior surface of the cornea to the sensitive plane of the retina and adding to this number the thickness of the sclerotic coat, viz., 1.3 mm., we obtain about 24.1 mm. as the length of the eyeball. Anatomical measurement has shown the eyeball to vary between 22.5 and 27 mm. in length, 24 to 24.6 mm. being the most common limits. Unfortunately these anatomical measurements refer mostly to eyes the refractive state of which was not determined during life. The

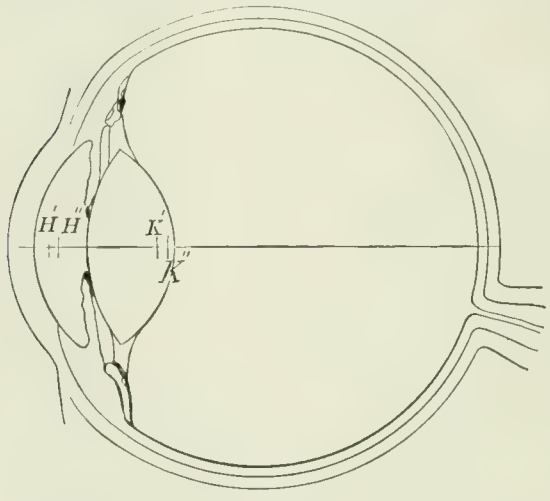


Fig. 2312.

diagrammatic eye of Helmholtz and the position of its cardinal points are illustrated by Fig. 2312, amplified twice.

26. In the calculation of the size of retinal images and of the influence of glasses on sight, in fact in almost all the problems not relating to the changes during accommodation, we can arrive at results sufficiently accurate by taking as a basis the simplified diagrammatic eye of Donders, in which the lens is omitted. It consists of a single refracting surface, representing the cornea with a radius of curvature of 5 mm. The single internal medium, optically identical with the cornea, has a refractive index of 1.333 ($\frac{4}{3}$). Thereby we deal with but one principal point, viz., in the plane of the cornea and but one nodal point, the center of curvature of the cornea. The first focal length is 15 mm., the second 20 mm., which latter figure represents likewise the length of this eye.

The human eye has some advantages not possessed by artificial optic instruments, but also various faults which a skilful optician can avoid.

27. *Visual Field.*—There exists no instrument which has as extensive a field as the eye, since images are depicted on the retina of objects situated as far as 55° to 65° from the line of direct sight, and on the temporal side even as far as 90° to 100°. The fact that images formed near the periphery of the retina are not seen distinctly, is due principally to the relative dulness of sensibility of the peripheral portion of the retina. The images themselves are quite sharp, as we can learn by examining the periphery of the retina in the eye of another person with the ophthalmoscope. When the refraction is emmetropic in the center of the retina, it is very nearly so also in the extreme periphery. This is due to the curvature of the rear of the eyeball and of the retina (compare Section 9). Moreover, the elliptical curvature of the cornea and, still more, the stratified structure of the lens prevent the distortion of images, which ordinary spherical, homogeneous lenses would produce in the case of objects situated far laterally from the axis of the system.

28. *Spherical Aberration.*—Spherical lenses do not collect in the common focus those rays which are very oblique to the axis or strike the refracting surface far from its center. This spherical aberration is shown in Fig. 2296. In the eye it is almost wholly obviated by the elliptical shape of the cornea and the stratification of the lens. The iris, moreover, serves the purpose of a diaphragm, so that the extreme marginal rays cannot ordinarily pass through the pupil.

29. *Chromatic Aberration.*—The chromatic aberration of lenses gives rise to colored rings around images otherwise well defined. It is due to the fact that the index of refraction is not the same for waves of light of different length. Hence there is necessarily a slight separation of the different colors when mixed or so-called white light is refracted by a lens. The eye is not free from this defect; it possesses it to about the same extent as if it consisted of water. If either end of a sharply defined spectrum be observed through an achromatic telescope the other end appears diffuse until the adjustment of the telescope (or of the eye) is altered. The difference in adjustment corresponds to about 1.5 to 2 dioptrics; that is to say, an eye forming a sharp image of an object emitting violet light, requires an additional convex lens of some 75 to 50 c.c. focal length, in order to bring the less refrangible red rays into a focus upon the retina. Ordinarily we are not conscious of this defect, because the eye is adjusted for the middle and brightest portion of the spectrum, viz., yellow and green to blue, while the red and violet rays form circles of diffusion around the image, which blend, and thereby diminish in distinctness of color, being, moreover, much less bright than the sharply defined image which they surround. But we can see these colored circles of diffusion quite distinctly on looking at some bright object, while covering one-half of the pupillary aperture with an opaque screen, for by thus cutting off half of the pencil of light, we prevent the blending of the color rings, and the object shows then a blue edge on one side and a yellow margin on the other. The chromatic aberration is also quite noticeable on observing a luminous point through a violet glass, which absorbs the middle part of the spectrum, whereupon we see either a red point surrounded by a blue halo, or a red margin around a blue point of light, according to the refractive state of the eye.

30. *Imperfect Centering.*—The optic system of the eye is not perfectly centered. The center of the cornea coincides, indeed, with the vertex of its ellipse; but the major axis of this ellipse forms an angle with the visual line, or line of direct sight; that is to say, the line of the ray of direction passing from an observed point through the nodal points to the center of the retina. The visual line deviates toward the nasal side of the corneal axis (proceeding outward) to an extent of from 4° to 8°. This relatively oblique direction of the corneal axis, when extreme, may give some eyes a false appearance of divergent squint. Still no noticeable deficiency of sight can be attributed to this want of centering.

31. *Astigmatism.*—More serious defects are those due to irregularities in the curvature of the refracting surfaces. We have so far considered only the refraction of rays which lie in one plane, with the tacit assumption that our refracting surfaces are the surfaces of true bodies of rotation, that is to say, that the radii of curvature are equal in all meridians. For, in this case, any of the figures illustrating the course of rays in the plane of the paper may be supposed rotating on their axis in order to illustrate the course of rays in all planes. But this assumption is scarcely ever correct in the case of the human eye. On measuring with the ophthalmometer the corneal radius of curvature in the horizontal, and then in the vertical meridian, the two radii are found to differ from each other to a trifling extent even in the most normal eyes. More commonly, but not always, the radius is smallest

in the vertical meridian. The two meridians presenting the greatest discrepancies are not necessarily horizontal and vertical; they may have any inclination. A difference of 0.1 mm. between the radii of two meridians at right angles to each other separates the focus of one meridian from that of the other to the extent of about 0.3 mm. Differences of 0.01 to 0.05 mm. in the radii are the most common. The cornea is hence the segment of an ellipsoid with three unequal axes. As a result, the focal length is not the same in any two meridians of unequal curvature, and hence the points of an object cannot be represented by points in the images formed in such an eye. If in Fig. 2044, *A*, we represent the ellipsoid cornea with the horizontal meridian *h h* having a greater radius of curvature than the vertical meridian *v v*, the focus in

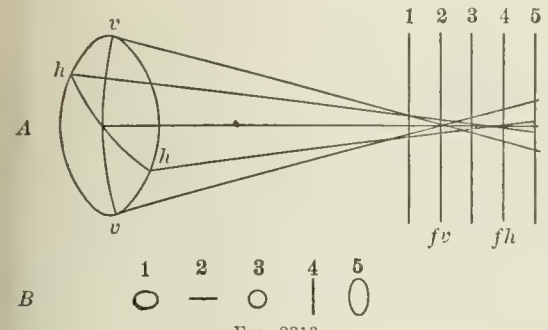


Fig. 2313.

the former meridian *f h* must be farther off than *f v*, the focus of the vertical meridian. If we place a screen successively in the positions numbered 1, 2, 3, 4, and 5, the image of a distant point would appear as shown in an exaggerated manner at *B*, 1, 2, 3, 4, and 5 of the same figure. The refraction by such an ellipsoid cornea can be imitated by means of an ordinary spherical lens, to which is added a cylindrical lens, the segment of a cylinder, thereby introducing a difference in the refractive strength in the two meridians, of which one is parallel with, and the other at right angles to, the axis of the cylinder. This defect of the eye is known as the regular astigmatism (from α, privative, and στίγμα, a point). There are very few, if any, eyes entirely free from it. When the inequality in the refraction of two meridians exceeds the strength of about one-half to one dioptric, it may necessitate correction by means of cylindrical glasses (see under *Astigmatism*). As the result of regular astigmatism, lines of different inclination are not seen equally distinctly. If, for instance, the eye be accurately emmetropic in the horizontal meridian, while the sharper curvature of the vertical meridian brings the focus behind the retina in the latter meridian, then only vertical lines at infinite distance will be sharply defined on the retina, while the more a line approaches the horizontal direction, the more diffuse will be its retinal image. The interference with sharp sight increases, of course, with the degree of astigmatism. A discrepancy between two meridians of less than half a dioptric does not interfere with sight to any practical extent.

Irregular Astigmatism gives rise to such slight imperfections of retinal images as the radiation of "rays" around stars and other small luminous points. It is due to optic inequalities in the different sectors of the lens, whereby some of the rays are deflected from the path which they would pursue in a perfect eye. This irregular astigmatism does not exist after the lens has been removed.

32. *Muscæ Volitantes.*—Few, if any, eyes do not at times see flying specks, so-called muscæ volitantes. They appear in the form of transparent [illegible] or groups of granules, or [illegible] floating about when the eye is moved. They are due to the presence of similarly shaped objects floating in the vitreous body, cells and groups of cells, and [illegible] of membranes, transparent, but of an index of refraction slightly different from that of the [illegible] surrounding them. Their rims [illegible] similar to those of a glass ball between a light and a screen. These shadows are most marked when the rays of light are parallel in the vitreous body, when the source of light is in the anterior focus of the eye. We can observe them well by [illegible] a pinhole in an opaque screen held close to the eye and toward the sky, or on looking into a microscope. When the attention has once been called to them they may continue to annoy nervous persons, mentally rather than optically. These shadows, even if inconvenient, are not indicative of any disease.

33. *Ametropia.*—The last and most important imperfection of the eye is the not uncommon want of harmony between the focal length and the anatomical length of the eyeball, the refractive defect known as ametropia. We have seen that the radii of curvature, the distance from cornea to lens, the length of the eyeball, and perhaps even the refractive indices, may vary within certain limits in different eyes. It is only in the more fortunate instances that the ideal result, viz., the coincidence of the posterior focal plane with the position of the retina, is obtained, while in many eyes, otherwise healthy, images of distant objects are formed, either in front of the retina, constituting myopia, or behind the retina, the condition of hypermetropia. In either of these two cases the retinal images of distant objects are blurred in proportion to the distance of the retina from the focal plane, and in proportion to the size of the pupil. The lower degrees of ametropia may be due to a disproportional curvature of the corneal and lenticular surfaces, while the length of the eyeball is normal; but when the anomalies of refraction reach any high degree, the eyeball is found, not merely relatively, but absolutely too long in myopia, too short in hypermetropia.

While emmetropia is the most fortunate refractive condition, it is not necessarily the most common. Statistics show that in the upper classes of schools, and especially high schools, in European countries, from one-third to one-half, and sometimes even two-thirds of the eyes are near-sighted, and some five to ten per cent. are far-sighted. In this country the figures are a little more favorable, as regards the frequency of emmetropia.

34. *Refraction during the Growth of the Eye.*—In the infantile eye all the dimensions are, of course, smaller than in the adult organ. The shorter axis of the eyeball is, however, proportionate to the shorter radii of curvature of cornea and lens, so that emmetropia can exist. Indeed, during childhood there are more emmetropic eyes than in adult life. The eyes of babes, however, are most frequently far-sighted, as shown by ophthalmoscopic examination. Jaeger formerly asserted the contrary, having found seventy-eight eyes myopic out of one hundred, and but five accurately emmetropic in new-born babes. He seems to have been misled, however, by the accommodated condition of the infantile eye, for later observers, who paralyzed the accommodation by means of atropine, have arrived at different results. Thus Eli found but 11 eyes myopic, 17 emmetropic, and 72 hypermetropic in 100 eyes of infants. Bjerrum noted 61 hypermetropes, 23 emmetropes, and 14 myopes in examining 87 babes. Horstmann found in 50 [illegible] infants 88 far-sighted eyes, 10 emmetropic, and but 2 short-sighted eyes. In 50 children, of the age of one or two years, 84 eyes were far-sighted, 10 normal, and 6 short-sighted; while in 50 children, four to five years old, hypermetropia had diminished, involving

74 eyes; myopia had increased to 13 eyes; 13 eyes being emmetropic. These figures show that the refraction increases ordinarily as the child advances in years. During the years of school attendance this growth leads, in many instances, to a myopic refraction. Indeed, as we pass from the lower to the higher classes in schools, we find myopia increasing steadily in frequency and in degree. The refraction remains stationary from the time of puberty, in healthy eyes. The increase of myopia so often noted from this time on until about the thirtieth year must be considered a morbid change.

35. Beyond the sixtieth year of age the refraction diminishes again, so that emmetropia turns into slight hypermetropia, on account of senile changes in the lens.

36. Accommodation.—According to the laws of refraction, the emmetropic eye can form sharp retinal images of those objects only which are situated at an infinite distance from the eye, or at least at a distance very large when compared with the dimensions of the refracting surfaces. Practically this amounts to any distance beyond five meters. But every-day experience teaches us that we can also see distinctly objects quite close to the eye; but we can never see equally distinctly, and at one and the same time, two objects, one far and the other near. On looking at a distant sign through a veil held in front of the eye, we can get alternately sharp images of the distant letters or of the threads of the adjacent veil, but we cannot see them both distinctly at one and the same time. This power of successive adjustment of the eye for distant and adjacent objects is termed the faculty of accommodation.

The exertion of the accommodation increases for the time being the refractive strength of the eye. It is evident that an eye accommodated for an object four inches distant must be equal in refractive strength to the emmetropic eye plus the strength of a convex lens of four inches focal length. For were the eye deprived of its power of accommodation it would be necessary to add to it the strength of this lens in order to get sharp retinal images of objects four inches off. The accommodative effort of an eye can therefore be represented by the strength of a convex lens of a focal length equal to the distance from the eye to the object accommodated for.

37. *Changes in the Eye during Accommodation.*—The optic changes upon which accommodation depends occur solely in the crystalline lens. Neither the corneal curvature nor the position of the retina is altered. Removal of the lens deprives the eye completely of its power of accommodation. Any eye, except one extremely myopic, becomes highly hypermetropic upon removal of the lens, requiring then a strong convex glass in order to see distinctly at a distance. On account of the impossibility to accommodate, the strength of this glass must be increased for near objects, and with a given glass accurate sight is possible only at one given distance. If the individual can read at different distances, it is done by ignoring the circles of diffusion, especially when they are small, on account of a narrow pupil. The most rigid test—whether in this or in any other case an eye is adjusted for a certain distance—is known as Scheiner's experiment.

38. *Scheiner's Experiment.*—If some luminous point—for instance, a pinhole in a screen in front of a light—be viewed through two pinholes in another screen which are closer together than the diameter of the pupil, the only effect of the latter screen held close to the eye will be to diminish the number of rays, and thereby reduce the brightness of the retinal image, if the latter be sharply defined on account of proper adjustment of the eye for the light. But if the eye is not adjusted for that distance, and circles of diffusion are formed on the retina, the screen with two perforations will cut off the rays forming the middle portion of the diffuse image, leaving instead two separate images of the luminous point, to which the eye is much more sensitive than to the circles of diffusion. Hence any want of adjustment causes the luminous point to appear double, as is evident from Fig. 2314.

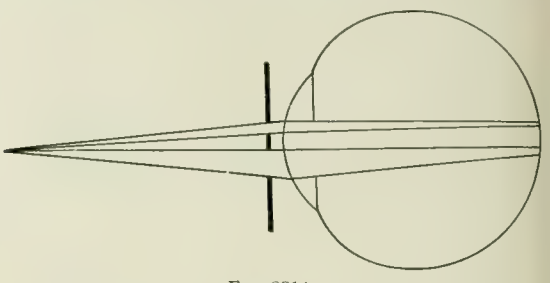


Fig. 2314.

39. *Changes in the Shape of the Lens.*—During accommodation the lens becomes more convex, especially its anterior surface, which also moves forward on account of the thickening of the lens. If we place a light slightly to one side of an observed eye and watch the images reflected from the various surfaces, they will appear as seen in Fig. 2315, *A*, while the observed eye looks as a distant object. When the eye observed is then adjusted for some near object, the images change, as seen in *B*, Fig. 2315. The corneal image, *a*, remains the same in both cases. The reflection from the anterior surface of the lens, *b*, diminishes in size, indicating increased curvature of the surface, and moves laterally toward the corneal image, a motion referable to the advancement of the anterior surface of the lens. The small, sharply defined, and inverted image (*c*) produced by the concave posterior surface of the lens shrinks likewise slightly in size, showing that the radius of curvature of that surface diminishes as well, though but little. No indication of any motion of the posterior surface can be observed. These changes in the curvature of the lens have been more accurately measured with the ophthalmometer, which shows that the radius of curvature can be reduced during a strong accommodative effort to about 6 mm. for the anterior surface, and about 5.5 mm. for the posterior surface of the lens, while the thickness of the lens may increase from 3.6 to 4 mm. Thereby the focal length of the lens in the diagrammatic eye would be reduced from 50.671 mm. during rest to 39 mm. during a strong accommodative effort. Calculating on this basis the refractive strength of the diagrammatic eye, we shall now find the principal posterior focus 1.644 mm. in front of the retina, while the retina itself is in the plane of focal reunion for rays coming from an object 146.6 mm. (not quite six inches) distant from the first principal point, which latter is 1.566 mm. behind the cornea in such an accommodated eye. Mathematical analysis thus confirms the theory that the increased curvature and the advancement of the front surface

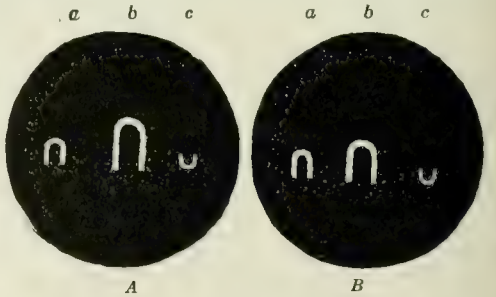


Fig. 2315.

of the lens suffice to account for the accommodative changes.

During accommodation the pupil diminishes in size. The utility of this contraction of the iris is evident on remembering that, according to Section 4, the spherical aberration would increase with the divergence of the rays, and hence with the proximity of the object. On account of the advancement of the front surface of the lens the iris is also moved forward, which can be seen on looking in profile view at an eye during accommodation.

40. *Mechanism of Accommodation.*—The accommodative changes of the lens are brought about by the action of the ciliary muscle. The lens itself is not a muscular organ, it is devoid of contractility. It is, however, an elastic body kept stretched by its attachment to the annular ligament, as an elastic hoop would be flattened by the traction of two cords attached at two opposite points. Relieved of this traction the lens increases in convexity and becomes more nearly globular, so that the lens removed from the eye is more convex and thicker than while in place. During the accommodation effort the ciliary muscle contracts. Its meridional fibers pull the chorioid forward. This has been shown by Hensen and Voelkers, by the movements of a needle put through the sclera and choroid on sending an electric current through the ciliary muscle in the eyes of animals and in a human eye extirpated on account of disease. The circular, ring-shaped muscular fibers of the ciliary body on contracting cause the ciliary processes to project further toward the center of the pupil, which movement of the processes is favored by the above-described traction on the chorioid and consequent relaxation of its anterior insertion. In eyes in which a sufficiently extensive segment of the iris has been removed by the operation of iridectomy, and through the translucent intact iris of albinos, this advancement of the ciliary processes toward the center of the pupil has been directly observed. Since the ligament of the lens is attached to the ciliary processes the crowding of this ring-shaped structure into a narrower space necessarily relaxes the circular band stretched across the aperture within this ciliary ring. Thus the lens is permitted to retract by yielding to the tension of its own elastic substance; for the arrangement of the fibers of the lens substance is such that they are relaxed by the approach of the lens toward the globular shape, while the flattening of the same by traction of its ligament puts them on the stretch. The changes in an eye during extreme accommodation are shown in Fig. 2316, in which the upper half represents the front half of the eye at rest, and the lower half the contraction of the ciliary muscle and its effect upon the shape of the lens.

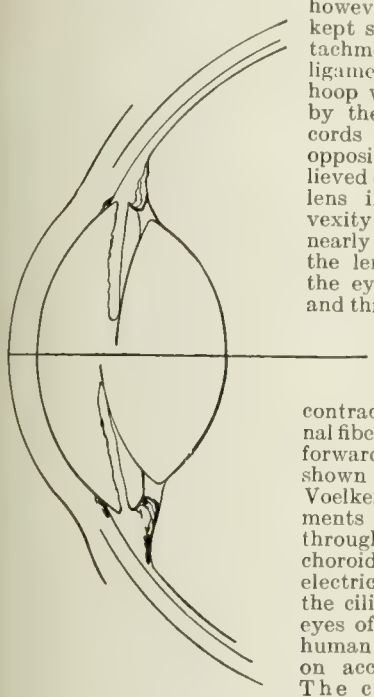


Fig. 2316.

41. *Range of Accommodation.*—The most distant point of which the eye at rest can form a sharp image on its retina has been termed by Donders the *far point* (punctum remotum = R) of the eye. In the emmetropic eye the far point [illegible] in our definition of emmetropia [illegible]. The myopic eye, however, cannot [illegible] beyond a certain short finite distance, depending on the degree of short-sightedness, while the hypermetropic eye cannot bring into focal [illegible] on the retina any but convergent rays, and the far point is therefore negative, that is to say, situated at some finite distance behind the eye. The fact that many hypermetropes can see distinctly at a distance with the unaided eye, is due to their using a part of their accommodation continuously in order to increase the actual refraction of the eye. The *near point* (punctum proximum = P), on the other hand, is the nearest point of which the accommodated eye can get a well-defined image. The range of accommodation is the total accommodative power which an individual eye possesses. We can represent it by the strength of the lens equivalent to the refractive difference between the eye at rest adjusted for the far point and the eye accommodated for the near point. Thus, an emmetropic eye, which can see distinctly an object as close as five inches, has a range of accommodation representable by a lens of five inches focal length or of the strength of about 8 D. For deprived of its accommodative power this eye would require such a lens to be held in front of it in order to get a sharp image of this near object on its retina. Practically, it will do to hold the lens very close to the cornea; for theoretical accuracy, however, the lens in question, of an infinite thinness, must be assumed situated in the first principal plane of the eye. The significance of the range of accommodation is made plainer by the use of Donders' formula,

$$A = P - R,$$

in which we represent by A the range of accommodation, by P the near point, and by R the far point. This formula is applicable to ametropic eyes as well as to emmetropia, for anomalies of the refraction do not necessarily alter the range of accommodation. Thus a myope whose far point is at twelve inches' distance, and who can accommodate for objects four inches from the eye has an accommodative range $= \frac{1}{4} - \frac{1}{12} = \frac{1}{6}$. Another instance will illustrate both the condition in hypermetropia and the use of the dioptric system. Suppose a certain hypermetropic eye, the axis of which is so short that it requires a correcting glass of 4 D in order to obtain sharp retinal images of distant objects. In this eye the far point is negative, that is to say, it is situated 25 cm. behind the anterior principal point. If this eye possesses an accommodative range equal to eight dioptrics, four of them are required to see distinctly at a distance and only 4 D are left, enabling the person to get distinct images of objects 25 cm. distant by the extreme employment of his accommodation. Donders' formula reversed expresses this on using centimeters as follows:

$$P = R - A,$$

which is in numerals

$$P = -\frac{1}{25} + \frac{1}{12\frac{1}{2}} = \frac{1}{25},$$

or employing dioptric notation, which is the reciprocal of the focal length,

$$P = -4\,D + 8\,D = 4\,D.$$

in other words, the distance of the near point from the eye is equal to the focal length of a glass of 4 D strength = 25 cm.

42. *Influence of Age on the Accommodation.*—From childhood on, the rigidity of the crystalline lens increases, and the extent of its elastic retraction diminishes. Hence the range of accommodation

diminishes as the years advance, because the lens cannot retract as much in the later period of life as during youth, though the contracting ciliary muscle relaxes the annular ligament. The range of accommodation sinks thus from beyond ten dioptrics, during childhood, to zero toward the age of sixty years. Donders has constructed a diagram (Fig. 2317), based on numerous observations, which illustrates this decline in a graphic manner. The heavy line (the lower one) represents the refraction of the eye at rest. As before stated, the emmetropic eye becomes slightly

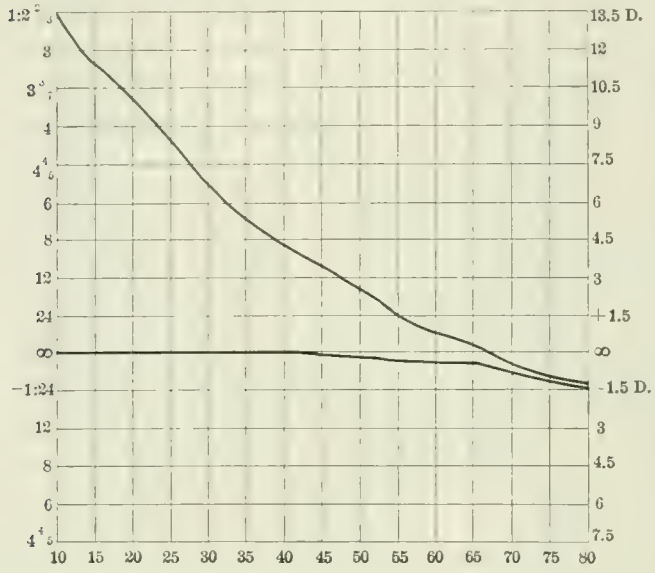


Fig. 2317.

hypermetropic in advanced age, presumably from an actual flattening of the lens or a diminution of its refractive index. The range of accommodation extends from the heavier line of passive refraction to the thin line indicating the extreme active adjustment of the eye. The figures at the bottom give the age in years; those at the side the (active or passive) adjustment in French inches (or expressed in dioptrics on the right side). Occasionally deviations are found from this standard of decline. Thus, among others, the writer has seen a gentleman, seventy years of age, who could read the finest type up to eight inches' distance. He had a slight myopia and myopic astigmatism, less than 1 D, so that this accommodative range was still a trifle over 4 D, a very unusual amount for his age. Exceptions of the opposite kind, a falling short of the accommodative range normal to the age of the patient, are always due to disease of the eye or general impairment of the health.

43. *Innervation of the Accommodative Apparatus.*—The ciliary muscle derives its nerve supply from the third cranial nerve or motor oculi, which sends the motor root to the ciliary ganglion, whence issue the ciliary nerves which penetrate the sclera. It is a common clinical observation to find paralyses of other branches of this nerve accompanied by paralysis of the mechanism of accommodation. Experiments by Trautvetter have shown that the fibers of accommodation run in the trunk of the motor oculi in pigeons, while in other animals the results were negative. In dogs, Hensen and Voelkers have traced the fibers up to the floor of the third ventricle of the brain, as shown by the result on stimulating those parts.

Although the ciliary muscle consists of unstriated fibers in mammals, its movements are both as rapid and as much under the control of the will as those of any striated muscle. In birds, indeed, having evidently a very energetic accommodative mechanism, the ciliary muscle is striated. While the ciliary movements are voluntary in a certain sense, we are ordinarily not conscious of any accommodative effort. The movements of the ciliary muscle are guided by the retinal impressions which we get of the objects viewed, and may hence be classed among the complicated cerebral reflex movements. The accuracy of these movements is wonderful, inasmuch as the most rapid changes of adjustment of the eyes for different distances never give rise to any blurring of the images for which the eye accommodates. The regulating mechanism does not miscalculate the distance of the objects. The accommodating movements are always accompanied by an exactly corresponding convergence of the two eyes, so that in normal instances the object accommodated for is also the one toward which both eyes are directed, so as to place its image in the center of the retina of each eye. The association of the movements of accommodation and convergence is so intimate that we cannot voluntarily perform either movement to any appreciable extent without the other. But by optic means, which simulate the effect of one or the other movement, we can temporarily rupture the association. Thus, with a given degree of convergence for a certain fixed object, we can either force ourselves to a greater accommodative effort by looking through concave glasses, or relax the accommodation by means of convex spectacles. Similarly, we can vary the degree of convergence associated with a certain accommodative effort by placing prisms of variable strength and inclination in front of one or both eyes. The ability to separate these two movements ordinarily associated is increased by practice. It is evident that the correlation of the two movements, as well as the disturbance of this association by optic means, subserves the same purpose, viz., distinct vision without double images.

44. *Movements and Nerves of the Iris.*—On account of the association with the accommodation, the movements of the iris can be best discussed in this connection. The iris serves the purpose of an optic diaphragm the aperture of which can vary in size according to necessity, the physiological limits being 1 to 6 mm. diameter. By reflex action the pupil contracts with increasing illumination, thereby diminishing both the fatiguing brightness of the retinal image and the width of any circles of diffusion due to optic imperfections. When the light is relatively feeble, a large pupil, on the other hand, permits a relatively greater brightness of the retinal images, while the enlarged circles of diffusion do not blur the sight so much, on account of their feebler intensity. The pupil contracts also with each accommodative effort, thereby diminishing the spherical aberration, which the proximity of the object and the increased convexity of the lens would produce. Independently of external light, the pupil is very narrow during sleep and during artificial narcosis. The mechanism of this latter contraction is not yet known. When the narcosis is interrupted by any sensory stimulation, or by asphyxia, the pupil indicates this change by dilatation.

The nerves of the iris are the ciliary nerves, coming from the ciliary ganglion, which, in man, has three roots—the short root from the motor oculi, the long root from the nasociliary branch of the fifth nerve, and the sympathetic fibers reaching the ganglion along with its arteries. The motor oculi controls the sphincter muscle of the iris. Its experimental irritation contracts the pupil; its section, or accidental paralysis, allows it to remain dilated. The reflex pupillary contraction produced by light starts with the excitation

of the optic nerve. When the optic nerves are rendered inactive by disease, the normal play of the pupils ceases, and they remain in a state of moderate dilatation. Excitation of one optic nerve, however, controls the pupils of both eyes, at least in those animals which, like man, have a visual field common to both eyes. Hence, in cases of unilateral blindness, the two pupils are usually alike in size. The center concerned in this reflex action is the anterior half of the corpora quadrigemina (Budge). Various instances of diseases of higher parts of the brain have been observed with integrity of these parts, and hence sensitiveness of the pupils to light, although conscious sight did not exist. According to Brown-Séquard the muscular tissue of the iris itself is somewhat sensitive to light, a tonic contraction being induced in it by strong light, even after extirpation of the eyeball.

The sympathetic nerve fibers control the dilator muscle of the iris. The existence of these radiating muscular fibers has been well established by the researches of Henle, Iwanoff, and Merkle, after much controversy with Gruenhagen. Their course toward the eyeball is partly along the walls of the arteries, partly along anastomoses which join the fifth cranial nerve. Section or paralysis of the sympathetic nerve of the neck is followed by contraction of the pupil, while its irritation dilates that aperture. These fibers can be traced through the rami communicantes of the last two cervical and the first two dorsal nerves into the spinal cord (Budge and Waller). The reflex center of these fibers is partly in the corresponding region of the spinal cord, and partly in the medulla oblongata. Reflex dilatation of the pupil through this nerve channel can be readily induced by any sensory impression through almost any sensory nerve, at least when the pupil is not contracted by strong light, especially during sleep and incomplete narcosis. The pupil, indeed, is very sensitive to irritations of sensory nerves. It is not known that this reflex dilatation is of any utility.

It has been asserted by Tuwim that the superior cervical sympathetic ganglion maintains a slight tonus of the dilator nerves of the iris, independently of, and even after its separation from, the central nervous system. Although his experiments seem conclusive, the question should be further investigated, since this would be the first instance known of tonic activity of nerves maintained by a sympathetic ganglion.

The fifth cranial nerve is the sensory nerve of the iris, endowing it with very great sensibility. Irritation of this nerve contracts the pupil very energetically in some animals, for instance the rabbit. Section of the nerve has the same effect, temporarily, the fibers being evidently kept in a state of transitory irritation by the injury, as occurs as well in certain other nerves. This influence of the fifth nerve upon the pupil does not exist in carnivorous animals. The observations in disease of that nerve in man are too conflicting to be decisive. The study of eye diseases attended with irritation renders it very likely that in man the fifth nerve is the vasodilator nerve of the iris, and that its reflex excitation congests the iris and contracts the pupil mechanically by the engorgement of the vessels. This is also the most plausible explanation of the intense pupillary contraction obtained on puncturing the anterior chamber, which result does not occur in operating on the dead eye.

H. GRADLE,
H. S. GRADLE.

Eye Diseases.—See *under Cataract, Choroid, Conjunctiva, Hypermetropia, Myopia, etc.*

Eye, Injuries of the.—Wounds of the eye may be confined to one or two of the structures only, or may involve the greater part or the whole of the globe. In the present article will be considered first the injuries affecting the individual parts and lastly the complicated injuries or those involving the entire globe.

INJURIES OF THE LIDS.—Injuries of the lids may be lacerated, punctured, or incised. Burns and gunshot wounds occur. All of these injuries may be complicated by contusion, and foreign bodies, the most common, usually are, being due to blows with the fist, sticks, stones, or other blunt instruments. Punctured wounds are caused by knife, or scissors-points, pens, pins, nails, bits of wire, metal, or glass; incised wounds by the blades of knives or razors or sharp pieces of glass, metal, or stone. In all such injuries, the connective tissue underlying the skin of the lid being loose, we have, besides redness, great swelling and more or less extravasation of blood; just as we have in bruises without laceration—the common black eye. Ecchymosis of the lids also occurs, as is well known, after fracture of the skull and after enucleation of the eyeball. It usually appears some hours after the injury and is confined to the lids by the closer application of the skin about the circumference of the orbit. No matter how severe, it is harmless and no effort to remove it through incisions should be made; this, indeed, by the production of new hemorrhages, would serve only to make matters worse. It is for similar reasons that in using leeches about the eye we apply them to the temporal side of the orbit and over the outer angular vessels.

Treatment.—So far as my experience goes, there is no royal remedy for a black eye; in two, or at most three weeks the disfigurement is pretty well removed, the result seeming to depend more upon the age and health of the patient, the rapidity with which tissue changes are taking place, than upon the topical remedies employed; though iced compresses at first are grateful and hot applications later may, perhaps, stimulate absorption. The treatment of lid-wound is simple. They must first be scrupulously cleansed with some antiseptic solution, weak enough not to injure the eye should some find its way between the lids; *e.g.* 1 to 4,000 bichloride. All particles of dirt must be removed. If there is much redness and swelling, iced compresses must be used until this subsides; and, if the wound be small, this may be all that is necessary. The important thing, if the wound be large enough to cause or to permit any misplacement of the lid, or if, even though small, it divides the free border, is to freshen the edges at once. Ragged bits should be removed as sparingly as possible, and as many sutures of fine well-boiled silk put in as may be necessary to restore and maintain the normal shape and position. A disk of moist gauze, a pad of absorbent cotton, and a two-inch flannel bandage should then be applied to immobilize the lid. This should be removed on the second or third day, when union should be complete, and the sutures cautiously withdrawn. A notch, the result of a scar, in the free edge of the lid, with the accompanying gap in the line of lashes, is not only more or less of a blemish, but is a perpetual annoyance, as the tears are squeezed out through it by every act of winking. When wounds of the lid are fresh, even though the laceration be extensive, though the lid be partially torn away, they are easy to repair. Any physician by the exercise of a little ingenuity and the observation of the position and landmarks of the sound lid, should be able to do a bit of repair work hardly to be equaled by the most expert specialist after the lapse of weeks or months. Not so, if he who first sees the patient neglects his golden opportunity. If we must wait for inflammation and swelling to subside, if cicatrices have contracted to form, distorting and displacing the lid, perhaps producing entropion or ectropion, then we face a condition which it may defy the most proficient to remedy with anything like to perfection. Nor are the instruments required unusual. Any small scis-

sors which cut clean to the points, a needle-holder, a small full-curved needle, a little fine silk or linen thread are all that we need. If the wound be superficial, the skin only may be sutured, but if it be at all deep, the suture must not only include the skin and underlying muscle, but must take a firm hold on the epitarsal connective tissue. Indeed, we may have to penetrate the whole thickness of the lid at one or two places to give greater solidity and firmness to our work; and this will do no harm if we are careful to see that the portions of suture on the conjunctival surface of the tarsus do not rub upon the cornea. If the free edge of the lid be involved one suture must be introduced perpendicular to the edge. That is, entering the free border some three millimeters to one side of the wound, it must penetrate and lie imbedded in the tissues of the lid for six or eight millimeters, cross to the other side of the wound and, still imbedded, come out on the free edge at three millimeters from the wound. When this suture is drawn up and tied, it will lie wholly upon the free border and the wound should be smoothly closed, one lip being no bit higher than the other. Such sutures are not difficult to pass if the lid be partially everted and held between the finger and thumb of one hand, for then the whole passage of the needle within the lid tissues can be distinctly felt and its point prevented from emerging either upon the skin or the conjunctival surface of the lid. When there is actual loss of substance of the free border it may be necessary to follow an ingenious suggestion due, I think, to Fuchs. This consists in making a small flap out of the free margin

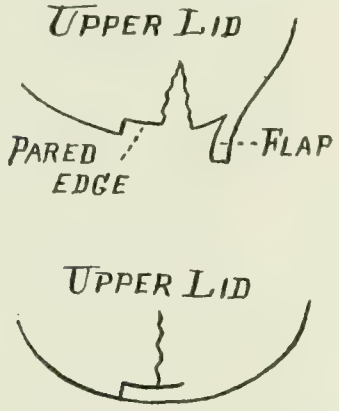


FIG.—2318. Plastic Operation on the Eyelid.

of the lid on one side of the wound just long enough to bridge the gap; about three millimeters high and as thick as the whole edge. On the other side of the wound, a portion of the free border exactly the size of this little flap is cut away. The flap being carried across and fitted to the pared surface and fastened by a suture through its tip, introduced perpendicularly to the free border, the gaping wound is smoothly closed. A glance at the diagram will make this clear.

Gunshot wounds produced by rifle or revolver bullets often lacerate the lids badly. Burns vary from the merest scorch to almost complete destruction of the whole lid. Sloughs on the skin surface are generally produced by burns, either chemical or thermal, rarely by necrosis following inflammation. They may be dealt with most successfully by grafting after the method of Tiersch or of wolf. The skin of the lids being thin, fine, and devoid of hair, material for grafting had best be taken from the skin of the inner side of the upper arm. As the area to be covered cannot, from the nature of the case, be large, the graft usually grows well. After it has been placed it should be covered with a disc of damp sterile gauze, or as Beard recommends, a thin layer of absorbent cotton wet with warm boric acid solution on which is put a well-adjusted pad of absorbent cotton covered with rubber tissue held in place, with pressure sufficient to immobilize the lid, by a nicely applied two-inch flannel roller, over which is thrown a wet mosquito-net bandage containing much sizing. This is left in place two or three days when the gauze is soaked off by patient irrigation with an undine. Sloughs of the conjunctival surface of the lid almost always cause the adhesions known as symblephara and, if they are extensive, even complete union of the lid to the eyeball—ankyloblepharon. With the many operations devised for the correction of this intractable condition, as well as those designed for the relief of ec- or entropion, or for the restoration of lids partly or entirely destroyed, it is not the province of this article to deal. Among the rarer injuries affecting the lids may be mentioned those of the nose or accessory parts producing emphysema. The air entering the areolar tissue of the lid causes great swelling without heat or redness and gives rise to a feeling of fine crepitation upon pressure that cannot be mistaken for anything else. Treatment is usually unnecessary. The air is rapidly absorbed as soon as the wound which permitted the escape is closed. It is evident that the victim should be warned against blowing his nose. The stings of wasps or bees and of other poisonous insects are productive of great swelling of the lid and severe pain. Cold and slightly alkaline compresses are most comforting.

Badly lacerated wounds of the lid have been inflicted by the claws and the bites of brutes and of man. Quite the most horridly lacerated and suppurating wound of the lids I ever saw was presented by a negro woman, a patient in the clinic. To my astonished question as to what could have brought the parts into such a state she replied in a thin flat voice: "I was bit by another lady."

Certain dangers peculiar to wounds of the lids must ever be borne in mind. The first is erysipelas, not an uncommon complication. In all cases of punctured wounds, we must assure ourselves by careful examination that the lid has not been penetrated and more important parts wounded. We should also be sure that a piece of the instrument by which the wound was made has not been broken off and lies hidden in its depths. Every practitioner of large experience has recovered from the orbit such foreign bodies. B. Carter's case of a three-inch hat pin is well known (Soelberg Wells), and Noyes relates a case in which the whole breech block of a gun remained concealed in the orbit, a part of it lying in the brain, without for a long time arousing suspicion. If in penetrating wounds, orbital fat protrudes, it must be cleanly cut away without pulling upon it. In all severe burns where there is great retraction of the lid, exposure of the delicate cornea can bring about the most disastrous consequences and measures for its protection will have to be taken. Deep wounds of the upper lid may divide the tendon of the levator and produce traumatic ptosis; a misfortune repairable by careful suturing, were it not that in such cases the innervating branch of the third nerve is often hopelessly injured.

Finally in the consideration of all wounds of the lids, whether accidental or surgical, it is to be noted that those parallel, or nearly so, to the free border will produce but little distortion, and, in the end, scars of but slight conspicuousness; while those perpendicular, or decidedly oblique, will have exactly opposite effects and consequences. All purposive incisions are, therefore, placed as nearly parallel to the free edge as the nature of the operation will permit.

INJURIES OF THE CONJUNCTIVA.—Susceptible as it is to many infections, the conjunctiva is as remarkably tolerant of injury as it is comparatively free from it. That is to say, in any large clinic one will see many more cases of conjunctivitis of microbian, than of

traumatic origin, and will observe the traumatic cases, if uncomplicated by injury of the more important parts of the eye, to be of shorter duration and less distressing to the patient. Not only cuts and punctures, but extensive lacerations and losses of substance heal promptly and without the production of obvious scars. An infected wound of the conjunctiva is uncommon. When we reflect that the membrane is both highly elastic and vascular, and is, except where it is attached to the limbus corneæ and the tarsus, but loosely applied to the lids and the eyeball, the reason of these properties becomes clear. We see, too, that it will rarely become necessary to suture conjunctival wounds. Therefore, when foreign bodies are imbedded in the conjunctiva we do not hesitate to pick up a bit of the membrane together with the offending body and remove both with a snip of the scissors. An attempt to disentangle a bit of metal from so loose a network of connective tissue is as effective as trying to unravel a cockleburr from a spider web.

A common foreign body in the conjunctiva is a grain of gunpowder. This being composed of almost pure carbon sterilized at the moment of explosion, does no harm though it remain indefinitely. If the number of such grains be large, and the patient be concerned about the cosmetic effect, many of them may be picked out after the conjunctiva has been anesthetized by the instillation of a four per cent. solution of cocaine; but at the expense of no little trouble. Beard recommends the use of H_2O_2 after waiting forty-eight to sixty hours. Liberal portions of the conjunctiva may be cut away, and in many operations large parts of the bulbar conjunctiva are removed; the adjacent edges being undermined, slid together, and secured by sutures. But burns of the conjunctiva are another matter. Whether caused by heat (molten metal, boiling fluids) or chemical action (acids and alkalies, lime the most common), they are, unfortunately, frequent enough. They heal much more slowly than other injuries and it is difficult to prevent union between the ulcerated areas.

The burned spot is at first of a dead white color, glazed perhaps with adherent mucus, and bordered by a red ring. In a day or so the surface becomes shredy or pultaceous looking and so continues until granulations form. Dark colored sloughs I have never seen but once, in the case of a girl reported to the American Ophthalmological Society in May, 1913, as an instance of ophthalmia artefacta.

Since the introduction of argyrol I have several times seen the conjunctiva burned with tincture of iodine by mistaking it for argyrol. In all cases the pain was severe, but the tincture having been promptly washed out in every instance, no injury followed. The sense of smell will guard us against such mistakes. It is well to remember that chrysarobin is so irritating to the conjunctiva that it should never be used about the eyes. After all injuries to the conjunctiva there will be extravasation of blood, edema (chemosis) and, of course, hypersecretion, more or less according to the severity of the traumatism. These need not alarm us. In about two or three weeks time the blood will have been absorbed and the membrane will, except in cases of severe burns or scalds, have resumed an almost normal appearance.

Treatment.—In the treatment of uncomplicated traumatic conjunctivitis, cold compresses (iced cloths) and the frequent instillation of a detergent, mildly astringent wash is all that is needed. The wash used under the name "B. and C." for all such purposes in the Eye, Ear, Nose, and Throat Hospital is made up of borax, ℈i.; boric acid, gr. x.; camphor water, ʒ.; and water to one ounce. With this the injured eye may be gently and freely irrigated from a Todd's undine. At the end of a week or ten days, should the progress toward recovery seem unsatisfactory, we may try cautiously the application of silver nitrate solutions to the everted lid, one or two grains to the ounce of water will be strong enough to begin with. If symptoms of iritis appear, a mydriatic must be employed in complicated cases, the instillation of a one per cent. solution of atropin sulphate often enough to maintain full dilatation of the pupil will be indicated and we should change our cold to hot [illegible]. In burns, nothing seems more soothing than the frequent instillation of a saturated solution of [illegible] in pure castor oil. If the burned areas be situated upon the surface of the lid and upon the usually visible portion of the eyeball, we try to prevent adhesion by frequently drawing away the lid, but if the burn is in, or extends to one of the culdesacs (fornices) this will be impossible. In spite of every effort the raw surfaces will grow together, and when healing is completed the adhesions will be stretched into bands or bridles of lesser or greater length, covered on the outer surface with conjunctival epithelium. Such a band is called a symblepharon, and is, especially when extensive, difficult of permanent release by surgery. The many ingenious operations for the relief of this condition, depending for their success upon grafting or upon resection with the formation of sliding flaps, do not, to repeat, come within the scope of this article.

A very rare condition, ophthalmia nodosa, characterized by the appearance of nodules or tubercles on the conjunctiva, is caused by the penetration of the hairs of caterpillars, or of some plants. The diagnosis is often suggested by the history of the case. A certain diagnosis is to be made only by excising the nodules—which is the treatment, and examining them under the microscope. De Schweinitz says (Text-book, Seventh Edition) that "violent conjunctivitis may be caused by the venom of certain serpents should this come in contact with the conjunctiva." Bad burns from bits of aniline pencil getting into the eye and remaining in the fornix have been noted.

Injuries of the Cornea.—The cornea is liable to the same injuries as the conjunctiva. The commonest of these are caused by small flying bodies which lodge upon its surface or become imbedded in its substance.

The epithelial layer of the cornea being merely the extension of the conjunctiva across its face, a fact long known, and the lodgment of these foreign bodies upon or in either of these membranes being commonly associated in practice, it is thought well to consider these injuries together here.

Foreign bodies on the conjunctiva of the globe, or in the lower culdesac, are usually promptly removed by whomsoever gives first aid and with the simplest means at hand—the corner of a handkerchief or the point of a pencil. If the body adheres to the surface of the upper lid its removal will demand ability to evert the lid. The amateur usually fails to accomplish this without an undue display of awkwardness and force because he does not know that to succeed his subject must look persistently downward. This done, if the thumb nail, a match, or pencil point be pressed down at the wrinkle that marks the upper border of the tarsus, while the finger and thumb that hold the eyelashes, or lid-edge, execute around this point a [illegible] forward, and upward, the lid turns readily inside out. It can be caught and held in position by the left thumb placed upon its edge; but, only so long as the patient continues to look down. The foreign body will oftenest be found in a little sulcus in the tarsus just within the free border and can be removed with any small, clean, probe-like instrument. Some of these bodies, either from their nature or their position, are worthy of a little consideration. As before said, if the fragment of metal, stone, or what not, be imbedded in the conjunctiva, it is

best to lay hold of it with forceps and remove it together with a bit of the membrane by a snip of the scissors; but glass in such a situation may give us endless trouble to detect it, and can only be found with certainty by feeling with a probe. The wing-cases of small beetles apply their concave sides like cups to the conjunctival or corneal surface, and in this way adhere with great tenacity. After remaining in the eye for some time and becoming partially covered with a little mucus they can sometimes be distinguished from ulcers only by close inspection through a good magnifying glass (binocular loupe) under strong illumination (oblique light). These bodies may slowly change position—MacKenzie cites from *Loders' Journal* the case of a priest, who, two years before, after momentary pain, had noticed a dark speck on the white of the eye above the cornea. After a time he was aware that the spot had changed its position to the limbus. "The speck continued its progress very slowly, but uninterruptedly; it came forward on the cornea, and at last covered a portion of the pupil. There was a prominent hard spot upon the cornea, equalling in size a small lentil; but longer than it was broad. Many small vessels appeared like streaks around it. The patient had no pain." On removal "it proved to be the hard wing-case of a beetle." Laborers in harvest fields are likely to get bits of the beards of grain into their eyes. These, from the set of their serrations, work into the upper fornix, soon become covered with mucus and the swollen membrane, and are hard to find. Indeed, no search for the cause of a monocular conjunctivitis can be called complete until, during cocaine anesthesia, the fornix has been explored with a probe or Daviels' Spoon. Formerly, seldom now-a-days, "Eye Stones" ("the flat opercula of certain mollusks," Duane) were often removed from eyes, into which they had been put to bring away foreign bodies.

Injuries to the cornea, even to the epithelial layer alone, are of vastly greater consequence than to the conjunctiva. This because of the rapid loss of transparency that follows every such lesion and because the non-vascular cornea, living precariously from hand to mouth, as it were, is immeasurably more liable to infection and its dire results. The liability will depend upon the nature and position of the wound; the state of the instrument with which it is inflicted, and the age and general health of the patient. Wounds of the center are much more dangerous than those of the corneal margin, which is nearer the supplies of nutrition contained in the vessels of the corneoscleral juncture; those cut by clean and sharp edges than those lacerated by rough and dirty ones. Children, in whom tissue changes are more active, will prove more resistant to corneal infection than their elders, in whom metabolism is comparatively sluggish; and similarly persons in full health than those of impaired vitality. Thus ulcers of the corneal center are much more likely to perforate, because the time required for them to become vascularized is so much longer than in the case of marginal ulcers. Abrasions made by the finger nails of children or by the leaves or stalks of plants, objects notoriously dirty, are very likely to become infected, and in old people often bring on ulcers that involve the whole cornea and so destroy the eye. On the other hand we see negro children with running noses, grimy hands, and in every way as dirty as the imagination can paint, in whom large cuts of the cornea heal promptly and smoothly.

Treatment.—Foreign bodies merely lodged upon the surface of the cornea may be readily whisked off with the cotton-wrapped probe, after the instillation of 4 per cent. cocaine hydrocloride solution (or 2 per cent. holocain), which is supposed to precede all explorations and distressing treatment of corneal injuries. The drug should, however, never be used frequently for a length of time to relieve suffering on account of its lethal effect upon the corneal epithelium. Even when the offending body has penetrated slightly the cotton-wrapped probe should be the first used, as it is the least damaging instrument save in expert hands.

After one or two failures with the probe, a towel should be put over the patient's hair, and the operator should stand behind him steadying the head against his chest with the hand that holds the lids apart. A light with a ground glass globe situated to one side and above should be concentrated upon the cornea with a lens held by an assistant, or the patient himself, or mounted in a frame held by a ring upon the surgeon's finger. By playing this oblique illumination over the surface of the cornea, the minutest particle will either be seen through the binocular loupe worn by the surgeon, or reveal its presence by a break or flaw in the reflection from the corneal surface. In cases of great difficulty, the instillation of a droplet of Merck's fluorescin solution, followed by repeated washings, will, by staining the depression in which the foreign body rests a vivid green, make it more conspicuous. This staining, too, renders great service in enabling us to distinguish whether we are dealing merely with the pit from which a foreign body has fallen, an abrasion, or whether the body is still present. The operator now places his blunt or sharp spud or needle (a sewing needle whipped through a flame will do in a pinch) just above the foreign body, for the eye is likely to be rolled up as the instrument touches it, and endeavors to turn it out with a quick, rotary flirting movement.

Our efforts are sure to enlarge the break in the epithelium, and the longer the body has remained in the eye the larger the area of destruction. It is well, however, that all the dead or dying epithelium should be removed, the wound will be the cleaner and will heal all the quicker. The charred and discolored rings about "hot sparks" should also be removed, though we need not be too particular in scraping away mere light rust stains. There can be no doubt that large numbers of eyes are lost or seriously damaged by infection through well-meant efforts at removing foreign bodies with knife blades, and other dirty instruments, on the part of fellow workmen or other amateurs, unhappily ignorant of the importance of asepsis in performing this, seemingly, trifling service. This danger has led to the adoption of an inflexible routine in the treatment of such cases in our clinic. The eye is cocainized, then stained with fluorescin. Under oblique illumination the foreign body is removed. Atropine sulphate solution (one per cent.) is instilled unless there be contraindications of age or tension. The eye is then thoroughly cleansed by repeated alternate instillations of ten per cent. argyrol and irrigations with B. and C. Finally a Blanco dressing, consisting of two discs of gauze holding between them a pad of absorbent cotton, and cemented to the circumference of the orbit with flexible collodion, is applied. This dressing is removed daily and the eye cleansed and treated with fluorescin. When the corneal injury ceases to stain the dressing is discontinued and the patient discharged. This precludes infection by dirty hands, handkerchiefs, etc., and saves long suffering and loss of time from after-coming corneal ulcer. The foregoing applies as well to the management of the superficial injuries known as erosions or abrasions of the cornea. A steel or iron foreign body that has penetrated the susbstance of the cornea must be drawn out with a magnet of adequate strength. In the case of other substances we shall have to cut down with a Graefe, or other small razor-sharp knife, and withdraw the foreign body with fine forceps. Should the body have penetrated the whole thickness of the cornea, so that one end lies in the anterior chamber, we must pass a narrow bent

keratome through the limbus, either to push it back or to restrain it from further penetration while we cut down upon it. Nature removes foreign bodies by necrosis of the corneal substance upon which they rest. This must often be a slow process, however, for I have removed scores of foreign bodies from the corneæ of negroes who asserted, and could give fairly circumstantial histories in support, that the accident had occurred weeks or months before. I have seen ciliary hyperemia, but not true iritis, follow this long retention of the foreign body. When the injured area has lost the gray hue of infiltration and has acquired a cream, or yellow color, infection has taken place. The eye should be at once thoroughly cocainized and the infected area lightly but completely touched with tincture of iodine on the end of the cotton-wrapped probe or of any small stick whittled down to a clean surface and suitable extremity. If the lids be held well away from the cornea until the application has dried perfectly, the pain will be entirely tolerable. The application may have to be repeated once or twice before the yellow hue is seen to disappear. It will rarely be necessary to ulcers of the margin. Atropine should now be instilled, if there be no contraindication, and the lid be immobilized with a disc of damp gauze and a pad of cotton held in place by a pair of hook temple spectacles, strong enough, and so adjusted as to produce the necessary pressure or if we prefer, with a Liebreich's bandage. This may be removed, and renewed every hour when the patient bathes the closed eye with stinging hot water and instills fresh ten per cent. argyrol solution. After some days, when the ulcer has become clean and stimulation together with further antisepsis should be beneficial, we may make light massage of the cornea through the closed lid after introducing a bit of yellow oxide of mercury ointment, at first of one and then of two per cent. strength. If the ulcer continues pultaceous or shreddy from the start, daily forcible irrigations with a fine stream of B. and C. or "normal salt" from an undine, a sort of hydraulic curettage, may be indicated. It is needless to say that attention should be paid to the general health; the bowels should be regulated, the patient should abstain from alcohol, the immoderate use of tobacco, indigestible food, etc. I do not think that well-being should be jeopardized and introspection and brooding be fostered by confinement to bed or to a darkened room; on the contrary, the patient will be diverted and improved by easy exercise, walking or driving in the open air, and by a rationally directed participation in his usual pursuits. At the proper time he should be warned of the inevitable result in scars upon his cornea and their effect upon his vision, should the ulcer have extended deeper than Bowman's membrane—into the true substance of the cornea. All uncomplicated wounds of the cornea may be treated upon these principles. Punctured wounds usually, lacerated wounds almost always, are complicated by injuries to other parts of the eyeball. The former are so small that our chief care when they are uncomplicated is to prevent the occurrence of infection before healing is completed.

When the cornea as well as the conjunctiva has suffered a thermal or chemical burn, the case is more serious. In chemical burns the prime requirement is to flood the eye, diluting and washing out the offending substance. It would seem that the selection and preparation of a neutralizing irrigating fluid (*i.e.* a weak alkali for acid, an acid for alkaline burns; strong syrup for lime, etc.) has greater theoretic than practical merit. He who first sees the agonized victim of such an accident is confronted with a situation demanding instant action. There is no time to gather materials and to make approved solutions. If there be nothing better at hand we must use the water from the first tap. An excellent wash, and one that is [illegible] households, is milk. It is [illegible] as are the secretions of [illegible] devoid of the rough [illegible] and it can be had in abundance. If [illegible] is at once within reach, the patient [illegible] held under the faucet and a gentle stream [illegible] into his eye, held open by his own and the surgeon's fingers. But where a vessel from which the [illegible] can be poured by an assistant is [illegible] patient should lie flat, the surgeon should hold the lids apart, and a copious, but not forcible stream should be poured into the eye. While [illegible] the surgeon by divers manipulations, pulling down the lower lid, drawing the upper lid away from the ball, from time to time everting it, not only causes the flood to reach every portion of the conjunctival sac, but by these movements of the lids, gently executed, he pushes or rolls out the offending material. Meantime four per cent. cocaine solution will have been obtained and instilled, and the patient's suffering being allayed, every particle of foreign matter, supposing it to have been solid, can be removed with a Daviel spoon, or similar instrument and the eye be cleansed thoroughly. After burns by exploding gunpowder, the black grains will be seen imbedded in the cornea as well as in the lids and conjunctiva and may be dealt with in the manner already described (injuries of the conjunctiva). The degree and extent of the corneal burn will be indicated by the ensuing opacity. In the slighter degrees, a larger or smaller area of the cornea will have assumed a pearly gray color; in severe burns the whole cornea appears as though overlaid by a thin layer of smooth porcelain through which neither the iris nor the pupil may be visible. If the cornea has been penetrated the prognosis is bad, but in the less severe burns the opaque cornea often clears up to a surprising extent and our prognosis should not be too gloomy. Burns caused by a droplet of molten metal are usually less severe than those from lime. The metal forms a thin scale between the lid and the eyeball and is rapidly cooled by the tears, while the lime acts for a long time on that portion of the eye with which it remains in contact. After all burns the eye will in a short time have become violently red, both the conjunctival and ciliary systems of vessels being injected, as in all severe affections of the cornea. There will be hypersecretion, pain, and photophobia. For these reasons we shall have to instil atropine and leave the eye unbandaged under a patch or smoked glasses, cleansing it frequently until the somewhat slow healing is completed. Pain, at first severe, may have to be relieved by narcotics, but the instillation of cocainized castor oil is very soothing. At all events some aseptic oily substance will have to be applied during the whole course of treatment. In burns, as in every case in which the corneal epithelium is destroyed, lead washes must be avoided on account of the opaque white deposits they cause. There is, indeed, no excuse for ever using them about the eyes, as many other substances are quite as valuable and entirely free from this objection.

After severe contusions of the eyeball we may find a gray, usually central opacity of the cornea. This generally clears up quickly with no further treatment than atropine, unless it be contraindicated, hot bathing of the closed eye and the use of smoked glasses. A similar opacity is said to be sometimes seen in the new-born, probably as the result of contusion, usually with the obstetric forceps. De Schweinitz says that such injuries may sometimes be severe and are perhaps the real cause of some so-called congenital leucomata.

Injuries of the Sclera. The sclera may, of course, be injured in every conceivable way; it may be

cut, punctured, lacerated, burned, or ruptured, but injuries of this membrane not involving other parts of the eye are among the rarest. Rupture usually takes place near the corneal margin and may be subconjunctival.

Treatment.—When the conjunctiva has been opened and the absence of infection at the time of the injury justifies an effort to save the eyeball, scleral wounds must be approximated accurately with the requisite number of sutures; for openings in this dense and tense membrane tend to gape to a degree commensurate with their extent. If a portion of the uvea and of the vitreous present in the gap, these must be cut away cleanly, with no more drawing upon them or pressure upon the globe than is unavoidable. Then, after careful cleansing of the eye (repeated B. and C. and ten per cent. argyrol solution washing; 1 to 5,000, bichloride irrigation), the sutures are introduced through the neighboring conjunctiva in such a way as to bring the lips of the wound in the sclera closely together. The silk used should not be too fine and the stitches should be placed from three to four millimeters from the edge of the conjunctival opening, or they will be sure to cut out before sufficient agglutination of the wound has taken place. Suturing the sclera itself does not seem justifiable; for wounds so large that they cannot be well closed by conjunctival sutures, must inevitably result in destruction of the eye; and the insertion of such sutures can hardly fail to produce further extrusion of the contents of the globe. The best way to proceed is to raise with the forceps, some three or four millimeters beyond one end of the wound, a fold of the conjunctiva as wide as the distance is to be between the points of entrance and exit of the line of sutures we intend to pass through the conjunctiva. Transfix this fold with a suture and tie, but do not cut it off. Now by drawing upon the threads thus left we can not only steady the eyeball more gently and with less pressure than with a fixation forceps, but we can lift the conjunctiva, ready for the next stitch, well away from the sclera. The same method may be followed with each succeeding suture, greatly facilitating our task. When surgical incisions are to be made through the sclera (*e.g.* posterior sclerotomy; cyclodialysis) it is best first to incise and undermine the conjunctiva; and to pass through it the sutures intended to close the scleral opening, drawing out the loops of the threads amply and laying them to one and to the other side. The operation being finished, the cut in the sclera can be closed immediately, before the escape of much vitreous and with the minimum of disturbance to the opened globe. Small unsutured wounds of the sclera will heal perfectly in an eye kept clean under a dressing which immobilizes the lid. Such a dressing is, in my opinion, of more value than cold applications. Atropine should be instilled to keep the iris and ciliary body quiet and the eye should be cleansed and dressed once a day. It is to be remembered that small perforations of the sclera, otherwise hidden, may be revealed by the almost total loss of tension of the eyeball. We should remember too that the prognosis even after these small wounds must be guarded, because the almost certain concomitant injury to the choroid and vitreous is likely to lead to ultimate detachment of the retina. The following case aptly illustrates all these points. A woman of about forty, in the last weeks of pregnancy, came saying that the day before she had overturned a seltzer bottle; it burst and a large piece struck her on the eye. There was a trifling cut on the upper lid of the left eye and at about three millimeters beyond the temporal end of the horizontal meridian of the cornea there was a Y-shaped wound of the conjunctiva and the sclera, about nine millimeters long in all. Tension was almost normal, and there was no choroid or vitreous visible in the wound, and no blood in the anterior chamber. Vision was finger counting at one foot and the ophthalmoscope showed huge floating vitreous opacities. This seemed to be a case of uncomplicated incised wound of the conjunctiva and sclera. Atropin was instilled, a pad held in place by hook-temple spectacles, which she was told to replace by cold compresses now and then, was put on and instillations of ten per cent. argyrol were ordered every two hours, with the warning not to strike or press upon the eye. Two days afterwards the wound was gaping slightly with a tiny bead of vitreous presenting. Two conjunctival sutures were placed. Twenty-nine days after the injury the wound was healed with a minute black spot at one point. Tension and all appearances of the eye were normal. The pupil being still widely dilated by atropin, the vision was equal to 20/LXX. The ophthalmoscope showed large floating opacities, but quite a fair view of the disc and larger vessels was possible. The doubtful nature of the prognosis was explained to the patient, and I saw her no more until fourteen months after her first visit. The sight of the injured eye, she said, had remained quite good until two weeks before. At this time V., L. E.=1. p. and R. E.=20/xx The ophthalmoscope showed in the L. E. an almost complete detachment of the retina. It is evident that it would have been wiser to have sutured the wound at the time of the first visit and to have closed the eye more thoroughly, but I do not believe it would have changed the outcome.

Injuries of the Uvea and Retina.—It is only by violent blows upon the eye that uncomplicated injuries of the iris, the choroid, or the retina can be produced. After such an accident it is common to see the anterior chamber filled with blood (hyphema). When after twenty-four hours we inspect the eye again, the blood will have settled to the bottom of the chamber as a thin crescent, or occupy its lower portion in a half-moon-shaped clot of a dark red color. The pupil instead of appearing round will have something of a kidney shape. Then we will observe, in light-colored eyes very easily, that the peripheral part of the iris corresponding to the flattened portion of the pupil is detached from its root, its insertion into the ciliary processes, giving rise to a new small, crescent-shaped, black pupil (iridodialysis). If light is reflected into the eye with and ophthalmoscope, this, as well as the natural pupil, gives back a glowing red reflection. Not infrequently so large a portion of the iris will have been torn away at the root, that it seems to stretch like the chord of an arc across the middle of the pupillary space. Sometimes close observation will show fine radial tears, running from the pupil edge into the substance of the iris. Fuchs thinks that such small lacerations are the most frequent cause of dilatation of the pupil after contusion, by reason of the weakening or paralysis of the sphincter they produce. Rarely these lacerations are large, and then, of course, the pupil seems widely dilated in the direction of the split. It is from these lesions of the iris that the blood we see in the anterior chamber has come, but we occasionally see hyphema when the closest inspection cannot discover any injury of the membrane. Instances of complete detachment of the iris from the ciliary body are known. Rarely a portion or even the whole of the membrane is inverted or turned back upon itself, and then seems either partially or wholly to have disappeared.

Treatment.—There is little or nothing we can do to repair the consequences of such happenings. According to most authorities the separated iris never becomes reattached, but Grüning says he has seen it occur once and cites another case from Berry (Norris and Oliver; System). Iritis rarely follows, yet it seems wise to put the parts at rest by the use of atropine; though dilatation of the pupil might be

supposed to favor the extension of radial lacerations. Certainly those cases treated by instillation of atropine and the wearing of dark glasses have, in my experience, recovered just as promptly as though many other things had been done. Though the injury to the iris may have little effect upon vision, the prognosis should be guarded for traumatic cataract not infrequently develops, even after the lapse of months, and there may be injury to other invisible parts of the eye (ciliary body).

Rupture of the choroid is the only uncomplicated injury which can occur to the remainder of the uvea; and this is true of the retina, which is sometimes torn at the moment that the vascular tunic is lacerated. As the result of the accident blood is usually extravasated into the vitreous, and the vision is, of course, obscured. In the great majority of instances coming under my observation the fact of the traumatism and a certain "strange look before the eye" have led to the ophthalmoscopic examination. This reveals, if the case be seen soon, a buff-colored crescent, bordered or splotched with dark red (blood), situated between the nerve head and the macula, sometimes higher, sometimes lower, and concentric with the disc. Later, as all blood is absorbed and the sclera shows more plainly through the tear, the crescent becomes more clearly white bordered, perhaps speckled, lightly with black pigment. Sometimes the ruptures are multiple, and smaller lacerations branch from the larger. The diagnosis presents no difficulty; the appearances are absolutely characteristic. If the retina has also been ruptured the retinal vessels do not pass across the tear in the choroid; their continuity is broken by the laceration. This is uncommon, but we must believe with de Wecker that it is impossible to suppose that the delicate nervous membrane can wholly escape injury. When all other effects of the accident have passed away a scotoma in the field of vision will correspond to the site of the cicatrized rupture.

Injuries of the Whole Globe (Complicated Injuries).—Although the development of the protective bony orbit has gone on together with that of the mammalian eye, it cannot be said to have kept pace, for serious injuries of the eyeball, involving many of its parts, are all too common. These embrace every form, contusions, punctures, incisions, lacerations, burns, and gunshot wounds with both bullets and small shot. The mode and the instruments of these accidents seem limited only by the range of possibility. I have seen them caused by chicken and rabbit bones, by a catfish and a crayfish thrown in a spirit of fun or anger. I once saw an eye dashed to pieces by the impact of an oncoming teal duck shot by a professional hunter. More than one case in which a rifle ball had passed through the orbit severing the optic nerve, but doing no other permanent damage, has come under my notice. Among artizans flying nails and staples or bits of metal, stone, glass or earthenware, penetration by wire, bursting cartridges, exploding dynamite, molten lead or iron and broken belts, and burns with acids, lime or ammonia or lye, are common causes of injury. Workers in the saw mills not rarely have an eye shattered by a large splinter ripped and thrown violently from the plank or log. Farmers are often injured by overhanging branches or by thorns, or stubble; by the kicks of horses, the horns of cattle and the spurs of cocks. Butcher's hooks, umbrella ribs, corks, bursting bottles, toy bows and arrows, blow-guns, slings, and air rifles have destroyed many eyes. The points of pens, scissors, knives, and forks are often driven into eyes by sudden jerks. Cutting kindling wood is a fertile cause of bad lacerations. Formerly many desperate injuries were inflicted by the bursting of the old-fashioned percussion caps. I have seen frightful lacerations caused by the cotton-hooks of the M[illegible] used as weapons. For practical purposes the most comprehensive groups into which [illegible] plicated injuries may be divided are the [illegible] and the reasonably hopeful.

In the former category must be placed those in which the eyeball has been widely [illegible] loss of much of its contents, with profuse intraocular hemorrhage, the lens perhaps, being extruded and the iris lacerated and prolapsed; all eyes in which suppuration in the vitreous [illegible] begun, at the time the patient is first seen. Here, as in all departments of surgery, the [illegible] judgment of the surgeon are all important in saving his patient long and useless suffering; in ophthalmic surgery with all the important addition—the sight of the uninjured eye. In such cases, a prompt enucleation will end in twenty-four hours severe pain that otherwise must last through weeks; and, in most cases, will permit the patient to return to a distant home within two weeks. In suppurating eyes, however, if it is evident from the nature of the injury that the infected contents must be spilled into Tenon's capsule or disseminated through the orbit in performing the operation, it is safer to cut away the whole cornea and much of the presenting iris, removing the lens if it presents, with the points of the scissors. Either operation will afford well nigh perfect protection from sympathetic inflammation. Both may be done, and in our clinic are done, except in the case of children, highly nervous persons or inflamed and very tender eyes, without a general anesthetic. Cocaine is instilled and ℥x. of the 10–10–20 solution (℥x. each of four per cent. cocaine hydrochloride and 1 to 1,000 adrenalin chloride and ℥xx. of one-tenth per cent. salt solution) are injected deeply along each rectus muscle. After eight minutes the operation is begun. Covering the seeing eye, the hypodermatic injection of a full dose of morphine an hour before and a stiff toddy fifteen minutes before are useful adjuvants. Such patients we never confine to bed or to the hospital; private patients prefer to keep to their rooms. The firm bandage and pad applied after the operation is discarded after twenty-four hours in cleanly patients and the socket well washed with sterile borax-water every hour; in the uncleanly the dressing is renewed daily the socket being well cleansed with ten per cent. argyrol and "B. and C."

Among the hopelessly injured must be placed also those eyes containing a foreign body which defies removal and those with penetrating wounds of the ciliary region. In each case, however, this statement requires qualification. In view of the many instances of sympathetic ophthalmia caused by eyes containing foreign bodies years after the infliction of the injury, it would seem the part of practical wisdom to act upon the theory that every such eye will cause sympathetic inflammation in its fellow should the patient live long enough. I have thought it prudent to enucleate an eye containing a small bit of a glass steam-gauge, because of severe symptoms of irritation in the uninjured eye, within forty-eight hours; on the other hand I have seen a confederate veteran lose his remaining eye by classic sympathetic inflammation after the other had harbored, without impressive resentment, a piece of copper percussion cap for forty odd years.

If, therefore, infection has taken place or if the foreign body has greatly lacerated or shattered the organ, especially in the ciliary region, or if in attempting its removal we should be obliged to [illegible] opening the sclera extensively, expressing the contents and causing profuse intraocular hemorrhage, it were best to proceed to enucleation at once. On the contrary, should the body be one not corrodible by the fluids of the eye, like charcoal or glass, should

the injury caused by its penetration be small, and, most important of considerations, should the wounded organ preserve a degree of useful vision, our advice, I think, will depend largely upon the intelligence of the patient and on his social condition. In persons of low intelligence, unimpressionable and of sluggish imagination, surrounded by those of like nature; especially, if belonging to a class that must seek a living wherever work is to be found, they may be here to-day and gone tomorrow; who, were they to be attacked by prodromic symptoms while in a remote neighborhood, would be unwilling and unable to abandon at once their work to seek skilled assistance in some city; in such cases it would seem our duty not only to advise, but to urge the excision of an eye containing any foreign body not readily removable. With persons of intelligence, appreciative of our advice and warnings, able at all times to command and to keep within reach of the best professional care, we may consent to temporize; all the more if the wounded eye heal kindly and remain free of irritability during the critical period, four to eight weeks after the injury. But in this case truth demands that we tell our patient that symptoms of sympathetic irritation, *i.e.* photophobia, lacrimation, weakness of accommodation in the good eye, do not always precede the outbreak of the dread disease. It may come "like a bolt from the blue," wholly unheralded, and the hope of saving even a degree of useful vision is then small indeed. I have lately seen a fine little boy of seven whose vision in his remaining eye is hardly more than one-tenth. His parents and physician, repelled by the idea of sacrificing an eye in one so young, had sought to temporize. Sympathetic inflammation had appeared in the uninjured eye over night and in spite of a hurried enucleation of its damaged fellow had left him well nigh blind. If the injured eye is blind and sympathetic irritation appear in its uninjured fellow we should at once enucleate, though if actual inflammation has begun we shall probably be too late. But it must be laid down as an inflexible rule, ever present in the memory, that once sympathetic inflammation has appeared in the uninjured eye, the injured eye, if it possess any useful vision, must never be removed; for it is quite probable that in the end, an end long maybe in coming, the (originally) wounded eye ("exciting eye") may preserve more useful vision than the uninjured, "sympathising eye." Nor should we be in haste to perform any operation looking to the improvement of its vision upon the "sympathising eye" after the disease has spent its force. Should we yield to the temptation, even after the expiration of a year, it is not unlikely that we shall see a recurrence of inflammation sweep away the results of the operation and leave the eye more useless, if not further upon the road to destruction, than before. These principles apply as well to penetrating wounds of the ciliary region. It has been my lot to see fewer cases of sympathetic ophthalmia caused by such wounds than by retained foreign bodies, but our literature does not lack examples. It has seemed to me that in the very young wounds of this region are less dangerous. True sympathetic inflammation makes its appearance as an insidious iridocyclitis. There is circumcorneal injection, some discoloration or "muddiness" of the iris, and a few adhesions between the iris and anterior lens capsule (posterior synechiæ) are formed. Very rarely the process stops here; recedes and recovery takes place. I have observed one such instance; but it usually goes on to complete destruction of the eye—atrophy of the globe. Rekindling of inflammation in such atrophic eyeballs may at any time be a repeated source of danger of sympathetic inflammation in the sound eye. If they are tender or irritable they should be excised. The labors of Haab in Germany and of Sweet in the United States have done much to simplify and illuminate the whole subject of foreign bodies within the eyeball; the one by the invention of his giant magnet, the other by the perfection of the method of localization with the *x*-ray. Radiography now permits us to know with certainty, almost, whether the eye contains a foreign body or not, where formerly we were often forced to surmise. The giant magnet enables us to remove with the least injury to the organ a large percentage of the steel or iron bodies that enter it, happily by far the greater number, if we follow the directions evolved from the enormous experience of its inventor. In this class of cases the magnet is usually diagnostic, as the patient generally feels a pang when the cornea is brought near the pole of the instrument. If applied soon after the body has penetrated, we succeed in saving a large number of useful eyes, and many sightless globes, that would otherwise have to be enucleated, are rendered innocuous. Both ophthalmic radiography and the use of the giant magnet are beset with difficulties and some dangers, and he who would use them has need both of study and experience. I do not, however, subscribe to the doctrine of extraction at any price. Remembering again the liability to detachment of the retina after even small scleral wounds, I am of those who prefer enucleation to continued attempts at extraction with divers instruments through large incisions in the sclerotica. Foreign bodies in the anterior chamber, rarely upon the posterior surface of the iris, may be allowed to remain if they excite no reaction, provided they can be watched by a competent observer. When symptoms of irritation appear they must be removed through an incision in the limbus. Iridectomy must be done if the body is entangled or the iris is in anyway injured before or during the operation. The most curious foreign body I ever met with was a No. 8. shot in the anterior chamber. It had entered the eye more than three years before and by its weight had formed for itself a little tunnel between the limbus and the root of the iris, into which it retreated out of sight when the head was erect. When the patient lay down and moved the eye quickly, it was thrown out upon the iris, over which it rolled like a ball on a billiard table. An incision was made in the limbus with a bent keratome and a Daviel's spoon introduced, in the groove of which, after a few failures, the shot was fortunately caught and withdrawn. The patient was discharged in a few days with V=20/100, which, he wrote later on, greatly improved.

Foreign bodies in the lens should not be disturbed. Cases are recorded in which the lens remained transparent in spite of the presence of a foreign body for a long time, the wound in the capsule having closed. If the lens becomes opaque it may be extracted, together with the body, by the usual operation, or in its capsule should the risk of dislodging the body seem great.

There now remain to be considered those complicated wounds in which infection has not been immediate or has been promptly checked; cases which, even though the ciliary region has been involved, permit, in our judgment, of repair and treatment in the hope that sympathetic iridocyclitis may be escaped, and finally those in which the eyeball has not been opened. The simplest of these is puncture of the cornea with prolapse of the iris. In such cases a complete excision of the prolapse must be the first care after the eye has been cleansed and cocainized. Even if reduction be possible, it is best not to replace the protruding iris lest it should carry something infectious from the conjunctiva into the anterior chamber. In recent cases, if the iris is put well upon the stretch with the forceps at the moment that it is cut by the scissors, it may snap back into position showing a well-made coloboma with clean

cut angles; or if this does not happen it may readily be reposited with a Daviel's spoon or Knapp's probe. This may be accomplished after a considerable lapse of time, but with increasing difficulty. Even though there should be some pus in the anterior chamber we need not despair, in younger persons. By strict asepsis, by keeping the iris and ciliary body at rest with atropine, by frequent hot bathing of the closed eye, by attention to the general health, and by evacuation of the pus by paracentisis or incision through the lower part of the limbus we may see the eye return to a healthy condition. It is in such cases that frictions, preferably on the forehead to relieve pain, with Arlt's salve (ung. hydrarg. ʒ j., extr. bellad. ʒ j.), a dram a day, are so useful. If the lens has been injured the patient or his friends should be warned that traumatic cataract is inevitable. Even though no injury can be perceived, the possibility of this sequel, so common after all severe injuries to the eye, should be mentioned. It is sometimes long in coming on and even longer in obscuring vision. I have lately seen a man whose right eye was injured some twenty-seven years ago. Although a star-like opacity was distinctly visible in the anterior layers of the lens the vision of the eye with his correcting glass was 20/xx and had remained so (under observation) for twelve years. With the ophthalmoscope the lens was nearly transparent and a good view of the uninjured fundus could be had Traumatic cataract may be discissed, after the eye has remained quiet for months, in persons of suitable age, the younger the better (arbitrarily not over 30 years). The operation should not be performed unless good light-projection has been preserved. If the fellow eye be good the chief advantage of the operation will be the resulting enlargement of the field of vision (unless the patient chance to be highly myopic) and nothing more should be promised. It should be remembered that if the capsule of the lens be opened by a small wound through the cornea, either at the time of the accident or by the discission increase of tension, great pain and redness (acute glaucoma) may be caused by the pressure of the swollen lens and choking of the drainage angle (corneo-iritic angle of the anterior chamber) with cortical débris. For this condition there is no remedy but an incision in the limbus with a bent keratome, and evacuation of the lens-stuff with a Daviel's spoon (linear extraction).

In complicated incised or lacerated wounds of the cornea, much the same conditions must be met by similar means. Here we may have not only to excise the prolapsed iris, but also to clear the lips of the wound and the anterior chamber of shreds of lens capsule and cortical matter by the use of the Daviel's spoon. If the flaps of the wound, swollen by inhibition of aqueous humor, fit badly, the conjunctiva may be incised all around close to the limbus, dissected well back and be drawn and closed over the wounded cornea by a purse-string suture. If we fear to cut off our view of the wound in this way lest infection should occur unnoted, we may undermine flaps of the conjunctiva, from the corneal margin back, at advantageous positions and stitch them together over the cornea in such a way as may best hold the wound edges in apposition. With these procedures I have, however, no experience. Rupture of the cornea by a blow is very rare, because under excessive violence the sclera bursts, near the limbus, rather than the cornea. Blows so forcible as to cause this result usually produce widespread ruin of the organ. For the lesions of the iris we can, as already said, do nothing, but cut away its prolapsed portions. The eyeball being a spherical elastic capsule filled with practically incompressible fluid, "the traumatisms," as Grüning well says, "due to contusions are prefigured in the anatomy of the organ, and present clinically the ever recurring pictures of mydriasis, hyphemia, [illegible] of the lens and rupture of the globe." [illegible] been dealt with in their proper places with the exception of dislocation of the lens. The [illegible] any extent; from a mere tilting of the lens in the patellary fossa (of the vitreous), or its displacement in any direction within or beyond the pupillary area, to complete dislocation into the vitreous or into the anterior chamber. There may be [illegible] these total and subluxation, [illegible] dislocation through a rent in the sclera or extrusion and loss of the lens through such a wound opening the conjunctiva also. Dislocation of the lens is usually the result of direct violence, but instances of rupture of the suspensory ligament (zonula) from [illegible] the head, the shock of a fall and execution by hanging have been recorded. Whenever the zonula is broken in any part of its extent movements of the eye cause tremulous movements of the lens and of the unsupported iris (iridodonesis). This then is the prime symptom of displacement. If the lens is completely dislocated into the vitreous, the anterior chamber will be of excessive depth, the refraction of the eye will be wholly altered (high hypermetropia) and the reflection of a candle flame from the surface of the cornea only will be seen upon examination in a dark room: the two images reflected at the anterior and posterior surfaces of the lens will, of course, have disappeared. In partial dislocation the light gray lens, its edge shining brightly (total reflection), is seen of a half-moon or gibbous shape in the pupillary area, if we view it by oblique illumination while it is still transparent. That portion of the pupil from which no light is reflected by the lens appears, on the contrary, intensely black. Through these two portions of the pupil, further examination shows a wholly different refractive condition. The lens released from the pull of the suspensory ligament assumes a highly convex shape, and thus causes myopia in the portion of the pupil occupied by it; while the portion from which the lens is absent requires that a strong convex lens be placed before it to restore acuity of vision. We thus have the appearance of myopia and hypermetropia in the same eye, and patients sometimes complain of monocular double vision. When the lens has been dislocated into the anterior chamber, this appears of abnormal depth, the released lens having taken on its utmost convexity. Besides the peculiar pellucidness thus given to the eye, the bright golden glow imparted to the periphery of the chamber by total reflection from the lens edge is both beautiful and unique. It looks, says Fuchs, as if a great drop of oil were lying in the anterior chamber. Instances in which the lens has been jammed and fixed in the pupil, giving rise to great irritation, have been reported. These observations may be more readily made if the pupil be dilated; and in this way the wholly dislocated lens may be sometines seen lying at the bottom of the vitreous chamber or may be observed to flit or bob across the pupil when the eye is suddenly moved. When the dislocated lens causes no symptoms of irritation it should be let alone and the patient be made as comfortable as possible by correction of the refraction. Should symptoms of irritation or inflammation appear, the lens must be removed. Very rarely this may be accomplished in young subjects by discission. Usually, the discission needle instead of entering the capsule, pushes the lens before it into the depths of the vitreous. As a rule we must proceed to extraction, and [illegible] the necessities of the case, to extraction in the unruptured capsule, by means of a vectis or scoop. The operation is hazardous, both as to its immediate and its remote results. Dislocation of the lens means that the zonule has been broken through and no partition any longer separates the aqueous from the vitreous chamber. Immediately, therefore, upon the completion of the section in the limbus, which must

be large to admit of the passage of the unbroken lens, the vitreous begins to escape, and the loss may be made excessive by the introduction of the vectis and our efforts to engage the lens in its loop. It is best in completing our section to have as large a conjunctival bridge (not flap) as possible by carrying the incisions in the conjunctiva as far back along the ball as we can, the eye being rolled downward. The bridge of conjunctiva thus lifted from the ball greatly restrains gaping of the wound and holds back the vitreous. It quickly readheres and thus closes up and holds in place the corneal flap. I believe it advisable to make a large preliminary iridectomy whenever the symptoms are not urgent. If the lens has been dislocated subconjunctivally, it should be removed through an incision in the membrane made under strict aseptic precautions, any prolapsing vitreous and choroid should be cleanly cut away and the gap in the sclera closed in the manner described under uncomplicated wounds of the sclera. I may repeat, however, as a final word, that in cases in which the globe has been extensively opened or in which many of its parts have been injured and displaced, a prompt enucleation will prove, in the long run, to have saved our patient from much weary suffering for the attainment of a very small result.

It sometimes chances that after a blow on the eye there will be decided obscuration of vision without any lesion being discoverable by the ordinary methods of examination. The ophthalmoscope, however, reveals a grey haze of the central parts of the retina. This (commotio retinæ) is said, upon evidence obtained postmortem, to be due to the vitreous having been forced between the delicate constituents of the innermost retinal layers.

Foreign bodies entering the orbit may divide the tendons of the ocular muscles, giving rise to a paralytic squint. In such a case we might open the conjunctiva and capsule of Tenon to secure and reattach the divided tendon; but the same result could probably be attained with far greater ease by a tendino-capsular advancement after the manner of de Wecker. MacKenzie has recorded an extraordinary case in which all the muscles and the optic nerve were divided and the eye extruded by a fall against the worn, sharp ring of a key, held firmly in the lock. The man was so drunk that he fell asleep without knowledge of his injury. The next morning he was found bathed in blood, a linear wound was discovered in the upper lid and the globe, with portions of the muscles and an inch of the optic nerve hanging from it, was picked up from the floor. In all cases in which foreign bodies have entered the orbit we must be on the watch for symptoms of orbital abscess; they should be the signal for prompt surgical interference. The ease with which the thin orbital plate of the frontal bone may be injured or perforated by foreign bodies of some size entering the orbit with considerable momentum must also be borne in mind.

H. Dickson Bruns.

Eye Symptoms in General Disease.—Most of the ocular symptoms noticed in general diseases are discoverable by the ophthalmoscope; "with it, it is like walking into nature's laboratory and 'seeing the infinite in action,' since by its means we are enabled to look upon the only nerve in the whole body which can ever lie open to our inspection under physiological conditions, and to follow in a transparent membrane an isolated circulation from its entrance into the eye through the arteries to its exit in the veins." (E. G. Loring.) By its means we are able to study daily morbid changes from the slightest congestion to the most flagrant inflammation; and often through its agency, obtain the first warning of disease in some distant organ.

Rheumatism and Gout.—Acute articular rheumatism must be regarded as an infectious disease, although as yet no definite agent has been found; yet various vaccines are being used with good effect.

That these two diseases should attack the eyeball and its appendages at first glance may seem strange, yet when we consider it, it is very clear and reasonable, for we all know that gout and rheumatism primarily attack the joints and prefer the fibrous tissue elements of the body. Now the eyeball and the orbit in which it is placed practically constitute a joint.

The orbit, a bony cavity of considerable size, lined by periosteum, is filled by the eyeball, whose outer covering is in every particular similar to fibrous tissue, *i.e.* the sclera and cornea—and attached to these coats are muscles and tendinous connections, in other words the elements of a well-regulated joint.

Orbital periostitis does not differ in symptoms from other inflammations of the periosteum, save that it is more persistent if the rheumatic cause is not recognized and treated.

Tenonitis, or inflammation of Tenon's capsule, we see in two forms usually, one chiefly characterized by chemosis, and the other without it; it is the latter form that is followed by amblyopia and optic nerve atrophy, any chemosis serving as an outlet for morbid secretion in the capsule. With the chemosis there is swelling of the eyelids and deep injection of the eyeball, with the tissues of the eyeball firm and brawny.

The ophthalmoscopic picture may be normal or show signs of optic neuritis according as there is more or less pressure; if optic neuritis is severe it may lead to optic nerve atrophy.

Affections of the Intrinsic and Extrinsic Muscles of the Eye.—Paralysis of accommodation has been noticed after severe forms of acute rheumatism and gout; and I have seen the extrinsic muscles affected with "lameness" as the patients expressed it, these symptoms being relieved by antirheumatic and gout remedies.

Conjunctivitis, without doubt occurs frequently in gouty and rheumatic patients, the inflammation of the eyelids antedating the attack of the general disease. Appropriate internal medication and diet will give relief, without any special local treatment.

Calcareous deposits found in the Meibomian follicles are of frequent occurrence, and are always considered indicative of the general systemic condition.

Eczema of the eyelid is also a sequel of the general attack and gives much trouble from the attending itching.

Keratitis.—More accurately, kerato-iritis, as both tissues are apt to be inflamed at the same time. The inflammation of the cornea, is of the parenchymatous variety and is usually associated with articular rheumatism; it does not differ in appearance from the same disease in congenital syphilis.

The diagnosis of all ocular affections due to rheumatism or gout is made not so much from the local symptoms as from the obstinacy to the local treatment used, and the marked and rapid change when internal medication is used. Keratitis in gouty persons is occasionally characterized by a porcelain-like opacity. A band-like opacity of the cornea should always arouse suspicion of gout.

Scleritis or episcleritis, not due to injury, is always due to some systemic disturbance, generally in those having the gouty or rheumatic tendencies. Scleritis attacks only that part of the sclera anterior to the equator of the eyeball, and the inflammation may be either superficial or deep.

The superficial form, episcleritis, appears as a circumscribed patch close to the cornea margin, and is often found without pain and with very little, if any, swelling of the parts. It is apt to recur in different parts of the eyeball, leaving slight discoloration of a dusky hue.

In deep scleritis the inflammation being more vio-

lent, thinning of the sclera occurs, and subsequent bulging takes place, presenting a blue-gray appearance, due to the choroidal tissues showing through the thin sclera. There is no secretion except an increased flow of tears, and the inflammation is associated with much pain.

Iritis in those subject to rheumatism or gout, differs from other forms only in its obstinacy to treatment by local measures, and is cured only when antirheumatic or gout remedies are used internally.

Glaucoma is freely admitted to-day to be produced by a gouty or rheumatic condition of the system; the circulation in the blood of the products of suboxidation brings about disturbances in the intraocular circulation, causing pressure and a glaucomatous condition.

Optic Neuritis.—It is the well-formed opinion of the closest clinical observers that there is no doubt whatever that the rheumatic and gouty diatheses are the cause occasionally of optic neuritis.

Retinitis Hœmorrhagica.—We have on several occasions seen retinitis with hemorrhages due to gout, where the general condition had not produced any cardiac or renal disease.

An atheromatous condition of the retinal vessels seemed to be the only possible factor in causing the hemorrhage. The failure of vision took place suddenly, the ophthalmoscope showing a small hemorrhage to the outer side of the optic nerve and below the macula lutea.

Opacities in the Vitreous.—Many cases of opacities of the vitreous are found, supposed to be due to the faulty metabolism, producing gout and rheumatism, where hemorrhages are found in the vitreous, and by some authorities they are looked upon as pathognomonic of gout. The changes in the vitreous are usually bilateral, though rarely symmetrical.

Cataract.—It has been said with good reason, that when the physiological hardening of the lens is associated with loss of transparency, there is good ground for believing that there is an underlying pathological condition, and in the opinion of many the gouty and rheumatic diatheses are the common cause of chronic and subacute inflammation of the uveal tract. We have frequently seen patients with beginning opacities in the lens, who had rheumatism at the time of the examination and who had had previous attacks, in whom marked improvement in the lens condition followed proper internal medication.

Gonorrheal rheumatism is often associated with an iridochoroiditis of a severe form, the inflammation taking on a purulent type and frequently leading to blindness.

Diabetes.—Failure of vision is often noticed in diabetic patients before any general symptoms are recognized, and the ophthalmoscope may show cataract, retinitis, opacities, or hemorrhages in the vitreous; amblyopia is also observed.

Cataract, occurring in a diabetic, may be extracted without danger if the patient is previously treated for the general disease.

Retinitis is usually associated with vitreous hemorrhages; this is a point in favor of the diagnosis of diabetic retinitis rather than of retinitis from kidney affection. Infiltration of the retina is not seen often, and the optic nerve head is not swollen.

Amblyopia in diabetes is central and the visual field is not interfered with, but there is usually a central scotoma for red and green, and occasionally for blue. We may conclude that the defect improves with a diminution of the sugar, and increases with an increase in the quantity of urine; that it comes on rather suddenly, varying according to the diabetic condition, that it rarely produces blindness, but may result in partial atrophy of the optic nerve.

This class of cases may be very easily mistaken for *amblyopia ex abusu*, unless care is taken to examine the urine for sugar, as the symptoms are [illegible] the same; and as most men smoke [illegible] clude that this is the cause of the a[illegible]zowski, was probably the first to point out the [illegible] blance, and according to him the [illegible] difficult without an examination of the [illegible] betes can be diagnosticated by the amblyopia when no general diabetic symptoms exist.

All diabetic affections of the eye are the result of poor nutrition, produced by the circulation in the blood of the diabetic toxin, the more profound the poisoning the more marked the ocular changes.

Nephritis.—*Retinitis albuminurica*, or [illegible] is frequently the first symptom the patient [illegible] of, failure of vision being noticed first, before the general constitutional ones appear. It occurs as a complication in many cases of both acute and chronic nephritis, and in the albuminuria of pregnancy; it is most commonly found with the small granular kidney, but may be associated with any chronic form of kidney disease.

Both eyes as a rule are affected, vision is lowered, and many seek the aid of the oculist for glasses. We have seen many such cases, in which there were no pronounced renal symptoms, only the intraocular condition.

The ophthalmoscopic appearances are strikingly characteristic, and once seen cannot be forgotten. These are venous hyperemia, swelling of the optic papilla and the nearby retina, hemorrhages on the nerve head and in the nerve-fiber layer of the retina; irregularly shaped white spots in the retina arranged in a group and to its outer side; in the macula region fine white dots may be seen, some having a stellate appearance. These dots look very much as if a brushful of white kalsomine had been thrown upon the retina at this point. The arteries are smaller or normal in size.

Complete absorption of the infiltrations rarely takes place except in the retinitis following scarlatina and pregnancy. It would appear from the collected cases that about twenty-three per cent. of patients with renal disease have disorders of vision at some period of the disease.

In many cases the renal disease is well established before the eye symptoms present themselves, and very often the eye lesion is the first indication of general disease. Instead of the visual disorders in kidney disease being now looked upon as interesting symptoms in the progress of the disease, they have become an index of unsuspected kidney affection and a means of diagnosis.

Uremic amblyopia is most commonly seen in connection with the nephritis of pregnancy and scarlatina, but may occur in any case of uremic poisoning. The blindness is complete, and may come on suddenly or with a short period of dimness. The ophthalmoscopic appearances are negative.

Diseases of the Heart.—One of the most [illegible] affections of the eye due to heart disease is embolism of the central artery of the retina, due to a plugging of its caliber, and is more usually found in cases of valvular disease of the heart.

The retinal arteries are so dwindled as to be scarcely seen, and the retinal veins are dilated. There may be also hemorrhages scattered throughout the fundus, the retina being more or less opaque in appearance.

Hemorrhages without exudation may be frequently seen in the retina as a result of arthritis; these rarely produce extreme impairment of vision, their chief importance is the warning they give of the condition of the blood-vessels in the brain and the rest of the body. When such hemorrhages occur in the eye they are apt to be forerunners of hemorrhages into the brain.

Diseases of the Brain and Spinal Cord.—[illegible] *neuritis* occurs in about three-fourths of all cases of

tumor of the brain; it usually is bilateral and of equal intensity; the vision may be unimpaired at first and may be so throughout; in such cases the ophthalmoscope is of great value in making the diagnosis of the general disturbance. For a description of the ophthalmoscopic appearance, see *Choked Disc.*

Optic neuritis occurs in a considerable number of cases of abscess of the brain.

Anemia and hyperemia of the brain, do not, as a rule, affect the retinal circulation, this being regulated apparently by the intraocular tension. This fact is so well known by the ophthalmoscopist, that when he hears of cerebral hyperemia being diagnosed simply by the ophthalmoscopic appearance of the optic nerve he is incredulous. For it is only after some time and in congestion of the brain of some severity that the retinal vessels become changed.

In cerebral disease of children, the ophthalmoscope, in a series of observations, showed the following ocular changes: In sixty-three cases of intracranial disease, a morbid condition of the fundus oculi was seen in forty-seven; of these eighteen were cases of neuroretinitis, thirteen of neuroretinitis and papillary engorgement, four of congestion of the optic nerve, two of atrophy of the optic nerve consecutive, and six of atrophy.

In ten cases of *acute tuberculosis of the brain,* found at postmortem examination, seven had either neuritis or optic nerve atrophy. The writer has rarely seen tuberculosis of the choroid, it is certainly not so commonly seen in this country as in Europe.

Cerebral hemorrhage gives very rarely any ophthalmoscopic picture; but on the other hand, cases of retinal hemorrhage give warning to us of the probable future occurrence of hemorrhages into the brain.

Spinal Diseases.—The most common form of intraocular change in diseases of the spinal cord is at first congestion of the optic disc and later the resulting atrophy. If it be the spinal marrow which is diseased by anterior or posterior sclerosis, through the agency of the sympathetic nerve we have the ocular symptoms showing themselves.

In *Pott's disease,* the only ocular symptom seen is a flushing of the optic disc.

Locomotor ataxia causes atrophy of the optic nerves in about fifteen per cent., and this is more commonly an early rather than a late symptom. It occurs even years before the usual signs of incoordination, the optic nerve atrophy, and the Argyle-Robertson pupil being frequently the only signs to direct our attention to the spinal cord as a cause. In multiple sclerosis optic nerve atrophy may occur, but less frequently than in the posterior form.

Vision usually suffers very much in these forms of atrophy, and the color sense is also destroyed.

Functional nervous affections are attended by a series of disturbances of the nervous system in which no pathological findings are present. The ocular symptoms have a marked similarity, *e.g.* concentric narrowing of the visual field, with or without color change.

Hysterical amblyopia is usually unilateral, double more rarely; the amblyopia varies in some, the visual field being concentrically narrowed, and the color field generally being reversed, red is recognized further toward the periphery than yellow and so on; there are no ophthalmoscopic changes to be seen.

Hysterical diseases of sight begin suddenly and usually disappear suddenly.

Hysterical blindness actually exists; it is a blindness that is mental, and not due to any attempt on the part of the patients to deceive themselves or others; as Sir James Paget said, "They say, 'I cannot'; it looks like 'I will not'; but it is 'I cannot *will.*'" This affection is found in men as well as women, hence the etymology is misleading; in 1,000 cases of hysteria fifty were found in men, or one male patient in twenty. It has been said that the Latins and the Slavs are more prone to it than the other inhabitants of Europe.

The treatment, then, resolves itself into removing the patients from their homes and changing their environment, together with the use of such remedies and measures as are capable of startling and surprising the nerve centers.

Neurasthenia produces no objective evidence of disease in the media or in the fundus. Should the ophthalmoscope show anything abnormal it will be found to be caused by other conditions. Asthenopia is met with, also photophobia and lacrymation.

In *epilepsy* many ophthalmoscopic examinations have been made; in the early stages the appearances are normal, but later venous hyperemia is seen in the retina. Neuritis, neuroretinitis, and atrophy of the optic nerve, have been seen and reported, but we do not consider these as due to the epilepsy, but to other complications.

The fundus has been examined during an attack, when the arteries were found to be narrow, and regained their normal size when the attack passed off.

Syphilis.—The eye may be the seat of the primary sore, and the chancre may be on the lid or its margin or upon the palpebral conjunctiva. It has the same characteristics as on other parts of the body.

Iritis is very common and appears at an early stage associated with the secondary period; three-fourths of all the cases are said to be due to this affection.

Choroiditis may develop in every degree of violence; the inflammation may be diffuse or disseminated. These two forms can be determined only by the ophthalmoscope. It is only when the retina has become involved that changes in the fundus can be recognized, so it is more correct to call the inflammation *choroidoretinitis.* In syphilitic choroiditis we find hyperemia of the optic disc, and a hazy appearance of the surrounding retina, and perhaps a diffuse opacity in the vitreous; these opacities move about and confuse the ophthalmoscopic picture; the diminution of vision varies and does not appear to correspond to the ophthalmoscopic changes. Micropsia is often marked, more so for objects observed at a distance.

In the form of *choroiditis disseminata,* the ophthalmoscope shows localized exudations into the choroid, alterations in the retinal pigment and later atrophy of the choroid. These patches of exudation and degeneration become visible and vary much in shape and extent. The patches are white bordered by dark pigment; the white appearance is due to the absorption of the choroid and the scleral coat showing through. These patches may be on the middle portion of the choroid or scattered about toward the periphery; only one intraocular disease might be mistaken for this by a careless observer, namely, retinitis pigmentosa. The treatment is antisyphilitic. The prognosis depends entirely on the extent of the inflammation. Optic nerve atrophy might ensue.

The *conjunctiva* may be the site of gummata which may be upon it, or beneath its surface; they have been seen in the lacrymal gland. Gummatous tumors of the brain are of frequent occurrence. For the description of the intraocular changes, see *Choked Disc.*

Interstitial keratitis, is considered to be a congenital syphilitic affection, usually associated with deformities of the skull, and enlargement of the glands, and a peculiar formation of the teeth, known as "Hutchinson's teeth," having been described by that surgeon.

Toxic amblyopia is produced by many different substances. It may be due to either acute or chronic poisoning—in the first instance a large amount of the poison is absorbed at once; in the latter the system gradually becomes saturated.

Poisons which dilate or contract the pupils usually have the same effect on the blood-vessels of the interior of the eye.

Lead poisoning produces optic nerve atrophy; in fact, all of the various poisons taken into the system set up a form of optic neuritis usually going on to partial or complete optic nerve atrophy.

Quinine, osmic acid, and salicylic acid have occasioned blindness. Optic nerve atrophy has been caused by all of the exanthematous diseases, such as typhoid and typhus fevers, mumps, malaria, relapsing fever.

Alcohol is one of the most common causes of amblyopia; while there may be some eye symptoms in acute alcohol poisoning, such as paralysis of ocular muscles, anesthesia of the cornea, and marked congestion of the ocular and palpebral conjunctiva, they are not constant symptoms. Amblyopia potatorum, from the constant use of alcohol is the condition most frequently found.

Absolute blindness rarely takes place from the abuse of alcohol alone—ophthalmoscopically we find the optic nerve looking dull and soggy, and its outline is not clearly defined. Later the optic disc takes on a pallor to the outer side, and the indistinctness is absent—the media remain normal. It occurs in each eye usually. Frequently patients wait until they are unable to read before seeking advice. The lesion is an interstitial inflammation of the axial fibers of the optic nerve.

Abstaining from alcohol, and giving nourishing food, with good attention to the skin, and the hypodermatic use of strychnine in increasing doses up to one-eighth to one-fifth of a grain will usually give marked relief, unless atrophy of the optic nerve has gone too far.

Wood alcohol (methyl alcohol) has caused death and complete blindness in a large number of cases, during the past three years. The inhalation of the fumes has caused blindness, where sufficient air could not be breathed. Brewers use this substance with shellac to paint the interior of beer vats, and the workman having only a very small aperture for air, the fumes inspired cause poisoning and sometimes permanent blindness from optic nerve atrophy.

Anisette, a cheap form of liquor used mostly by Italian workmen, has been found to contain a large amount of wood alcohol, and many cases of blindness and sudden death have been traced to its use.

Tobacco amblyopia is caused by habitual and excessive use. It is usually found in each eye, though not necessarily to the same extent. The appearance of the nerve head is similar to that seen from alcohol; in each case there may be a scotoma. Complete abstinence from smoking, and the use of strychnine hypodermically will cause improvement.

Constitutional diseases, so called, cause eye symptoms of various sorts.

Leucocythemia often produces serious disturbances in the fundus, due to serous exudation through the vessels.

In *pernicious anemia* we have hemorrhages in the retina that vary from being extensive to being very minute. Edema of the eyelids is often seen, the ocular conjunctiva shows a yellow hue, and fine extravasations may be seen in this membrane.

In *Addison's disease* this same condition is noticed.

William Oliver Moore.

Eye, Tumors of the.—I. Tumors of the Eyelids.—A. *Benign Tumors.*—The benign tumors of the lids are partly congenital, partly acquired later on in life. Their growth is but seldom accompanied by any inflammatory symptoms. These tumors, of course, during their growth, are influenced by the nature of the tissue from which they spring and into which they grow, and the variety of tissues which constitute what we term [illegible] about a number of [illegible] endless variety in their shape.

1. *Warts* and [illegible] with epithelial growths) are sometimes [illegible] outer dermoid surface of the [illegible] the upper lid. They may be [illegible] may keep on growing [illegible] necessary to remove them on account of [illegible] sightliness, or because their weight is felt [illegible] and has become a hindrance to the [illegible] of the lids; or, finally, because they actually obstruct sight by obscuring a part of the [illegible] positions of the eyeball.

Such warts usually spring from the lid, with a broad basis. They are not easily confounded with epithelial growths, because they [illegible] inflammation and infiltration, which, in the case of the latter, is never wanting. Furthermore, epithelial growths usually show points of ulceration. Moreover, epithelial growths of the eyelids, although observed in young subjects, are more frequently found in the declining years of life, and lie most frequently near one of the canthi or at the lid margin. Warts and horns, however, are found in all ages, and seem to be more frequent near the middle portion of the eyelids than at any other locality.

According to their superficial arrangement, such epithelial warts of the eyelids have been described as papillomata when resembling cauliflower, and as condylomata when resembling the broad or pointed condylomata observed in other regions of the body.

The histological structure of these warts has nothing that would distinguish them from other warts of the skin. They consist of hypertrophic papillary structures, covered by very thick and horny layers of epithelial cells.

Although such warts are in themselves benign tumors, we must state here that in later years epithelial growths often begin from such warts, and their removal is therefore to be recommended.

2. *Granuloma* or *chalazion* of the eyelid is, in contradistinction to the other benign tumors of the eyelids, an inflammatory tumor. In its origin it is a hordeolum, that is, an inflammatory process caused, in the more superficial or the deeper layers of the eyelid, by the stoppage of one or more secretory canals of the Meibomian glands, be this merely mechanical (by foreign substances) or due to an infection or an inflammatory process, which only secondarily involves the secretory ducts of these glands. Such a Meibomian hordeolum is originally the distended Meibomian gland, filled with its own secretion and pus, and later on with an atheromatous detritus. This sac, so to speak, lies, as is [illegible] its mode of development, embedded within the tarsal tissue, and pushes out the skin of the lid in the form of a roundish elevation, the periphery of which falls off into the surrounding tissue at a more or less acute angle. These tumors vary considerably in size, and, aside from the deformity which their presence causes, they may have to be removed because they interfere with sight.

We find, then, usually, that these tumors (tarsal tumors, as they are often styled) consist, at a later period, to a great extent, or even totally, of granulation tissue, which, having sprung from the walls of the sac, has forced the semi-fluid contents of the original cyst to one side where they have undergone partial absorption. Later yet, we may find solid granulomata which now and then contain giant cells, and no vestige of the atheromatous or purulent contents of the sac. [illegible] that one author claims that chalazion is due to the tubercle bacillus, while another author has even found an enormous bacillus chalazicus.

This is undoubtedly the form of tumor most frequently met with on the eyelids.

3. *Xanthelasma* or *xanthoma* of the eyelids is not a rare affection. It seems, however, to be more frequent among females than among males. It is a roundish or lobulated elevation of the skin, of a peculiar yellowish appearance, which has given it its name. Its development has often been brought into relationship with diseases of the liver.

Very frequently these elevations occupy symmetrical positions on both eyes, especially in the nasal third of the upper eyelids. They are not found in early youth, and undoubtedly belong to the later years of life. In females they often develop in the catamenial years. Aside from the deformity which they cause, there is hardly any reason for their removal.

So far as their histological formation is concerned there can be no doubt that different forms of tumors which have nothing in common except their yellow aspect, may be taken for xanthelasmata. This yellow coloring is due to the presence, in the subcutaneous tissue, of a large number of stellate connective-tissue cells which contain yellow pigment

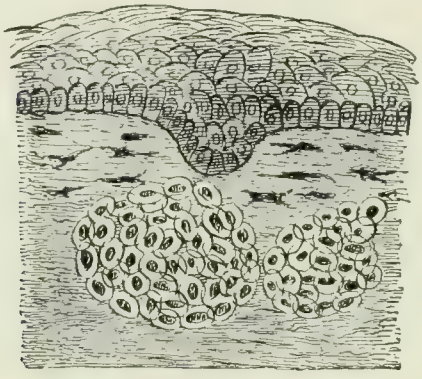


Fig. 2319.—Xanthelasma of the Eyelid.

granules. Aside from these, the tumor may consist of connective tissue which has undergone fatty infiltration and degeneration, or it may show plainly a hypertrophic condition of the sebaceous glands, with stoppage and perfect occlusion of their excretory canals. We find then, in these tumors, large, round sacs of connective tissue filled with the enormously swollen epithelial cells of these glands, which are undergoing retrogressive metamorphoses (see Fig. 2319). In other cases we find simply a dense connective tissue, void of even a trace of the glandular structure, but containing the pigmented, stellate cells which these tumors all have in common, and from which they derive their name. The same enlarged and degenerated epithelial cells are found in molluscum contagiosum and have been claimed to be the characteristic molluscum bodies. They are, however, also found in epithelial horns and other pathological conditions of the lids.

According to their form, these tumors have been described as xanthelasma planum or tuberosum.

4. *Cysts* are sometimes observed in the eyelid which are not to be confounded with chalazia in a cystic stage. Such cysts, of which the writer has had occasion to see an enormous one, appear as more or less round semi-transparent protrusions which may cause a pressure atrophy of the tarsal tissue so that they lie apparently enclosed only between the stretched conjunctiva and the skin. They take their origin from the sebaceous or modified sudoriferous glands of the skin of the lid margin.

5. *Angiomata* of the eyelids are almost always congenital tumors, although, from their slow development, they may become noticeable only several years after birth. They belong either to the cavernous or the arterial variety.

The cavernous angiomata cause a swelling of the lid in which they are embedded, and usually impart to it a dark blue color. If the upper lid be the one affected, it cannot be raised freely, or else it shows the condition known as ptosis. Any impediment to the continuous flow of the venous blood (stooping down, coughing, pressure, etc.) causes the tumor to swell. These growths frequently extend backward into the tissues of the orbit, or into the tissues surrounding this cavity. From their site, color, and conformation, such cavernous angiomata may be, in rare cases, confounded with orbital cysts, which sometimes cause a very similar aspect of these regions.

The histological structure of these cavernous growths shows, of course, nothing peculiar.

The teleangiectatic tumors are usually smaller than the cavernous ones, and since they generally reach to the cutaneous surface, they are recognized at a much earlier period. There is very often but little or no swelling, but the bright red, enlarged blood-vessels can be seen through, or even in, the skin. This kind of angioma is but seldom confined to the eyelid alone. Yet there are also teleangiectatic tumors of the eyelids so well defined that they can almost be enucleated like a granuloma.

While cavernous angiomata are apt to grow with advancing years, the teleangiectatic angiomata do not seem to have this tendency to a very marked degree.

6. *Fibromata.—α. Hard fibromata* of the eyelids are of very rare occurrence, and may possibly take their origin from a granuloma formed in the cystic distention of a Meibomian gland (hordeolum). The writer has seen and examined only two such cases. In both, the round tumor was implanted in the tarsal tissue, and raised the skin of the lid just as a chalazion does. In both, the tumor was situated in the upper lid and was harder to the touch than a chalazion usually is. The size of the tumors was about that of a cherry pit, and they consisted altogether of a dense tissue formed of short spindle cells.

β. The *soft fibroma* (fibroma molluscum) of the eyelids is also of very rare occurrence, and is usually found at the same time on other parts of the body.

These tumors, which appear always in large numbers, vary in size from that of a pea to that of a large pear, and even much larger ones have been observed. As they grow they usually become pedunculated, and hang pouch-like by this pedicle.

Their histological structure has not as yet been satisfactorily studied. Some authors have found only soft connective tissue, while others report the presence of peculiar cells undergoing retrogressive metamorphoses—probably epithelial cells of the sebaceous glands, resembling closely those found in xanthelasma.

γ. A third form of *fibroma* of the eyelid has been described as *plexiform neurofibroma*. This rare kind of growth is said to be congenital, and to consist of a series of swellings and cords which lie in the subcutaneous tissue, and which in parts are extremely painful to the touch.

The histological examination has not cleared up the nature of these fibromata very materially. They are said to consist of dense connective tissue, rich in nuclei, and surrounding simply atrophic nerve bands, or nerve fibers undergoing fatty degeneration.

7. *Lipomata* of the eyelids are of rare occurrence. They may be congenital, or they may appear in very obese people in advanced life. In the latter case they are apt to grow, and may have to be removed because they interfere with the sight, and this is especially apt to be the case when they develop in the upper lids and hang over the lid margin.

No further importance is attached to this kind of growth.

8. *Lymphangiomata* and *lymphomata* have also been found in the eyelids.

9. There is another rare form of tumor of the lid, which takes its origin from the lymph vessels, which has been called *lymphangio-endothelioma*. It is chiefly made up of the endothelial cells of the lymph vessels enormously increased in numbers and embedded in an edematous connective tissue which sometimes contains patches of cartilage or bone tissue.

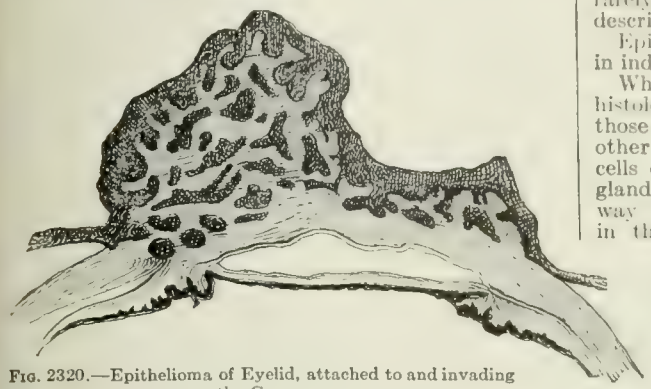


Fig. 2320.—Epithelioma of Eyelid, attached to and invading the Cornea.

In a case reported as lymphangioma the tumor is said to have been situated at the lid margin, the size being that of a split pea. It consisted of fibrous connective tissue, throughout which were scattered a large number of cavities of different sizes. These cavities contained a fine, granular substance in which lymph cells were suspended. The walls of the cavities were lined with an endothelium.

In harmony with this description the tumor was styled a cavernous lymphangioma. A number of cases of a similar nature have since been described.

Lymphomata of a very large size were found in all the four eyelids of a man suffering from leukemia.

B. *Malignant Tumors of the Eyelids.*—1. Of the malignant tumors of the eyelids the most frequent are *epithelial tumors*, and among them especially the flat epithelioma.

The epithelioma of the eyelid begins almost always at the lid margin, especially on the lower lid, and it seems to grow with preference near the inner or outer canthus.

In the beginning we usually find a small, roundish, reddish nodule, which is quite hard. Sometimes this hardness and some redness around the original nodule are the only symptoms by which we may distinguish it from a common wart. After a while, either spontaneously or because the patient keeps irritating it with his fingers, the surface of this nodule becomes slightly ulcerated, and a crust is formed. Now this one nodule may keep on growing and spreading, and become excoriated at its surface, or new nodules may spring up around it and share the same fate. Thus there is finally developed a flat ulcer, with a hard base, and hard, ragged edges, which frequently bleed profusely when but slightly injured. As the ulcer creeps along some parts may heal, and the tough white bands of scar tissue give the affection then an aspect very similar to that of scirrhous cancer in other parts of the body. The infiltration of the tissues, the breaking down of the lid margin, and the development of bands of cicatricial tissue—all these alterations, singly or combined, may cause very annoying and unsightly deformities of the eyelids. The lower lid, as a rule, becomes everted, and to all other afflictions is added a continuous flow of tears. The growth of this kind of epithelioma is but slow and, *quoad vitam*, very much less to be dreaded than another form of the [illegible] rapidly into the tissues and [illegible] very short period. In the latter [illegible] progress of the primary disease [illegible] infiltration of the lymphatic [illegible] parotid, or the disease may spread [illegible] tiva bulbi into the cornea, and, [illegible] it, may enter the eyeball, or grow around it and invade the tissue of the orbit. This form is, luckily, observed rarely, and the prevalent forms [illegible] described.

Epithelioma of the lid is a disease [illegible] in individuals of advanced age only.

When this form of tumor involves the eyelid the histological elements found are [illegible] those observed in the growth when it involves some other part of the body. The pre-existing epithelial cells of the cutis, as well as those of the sebaceous glands, become hypertrophic, and grow in the typical way into the underlying and surrounding tissues in the shape of cylinders. Frequently the rapid increase in number of the epithelial cells causes the formation of pearl nodules. The periphery of the growth shows the usual zone of infiltration and inflammation.

2. *Adenoma* and *adenocarcinoma*, especially of the Meibomian glands, but also of other glands in the tissues of the lids, have been found in a number of instances. When seen at the proper time it has been found that what originally was an adenoma had developed, later on, a carcinomatous character.

3. *Sarcomata* of the eyelids, at least those of primary nature, have been observed in small numbers (about fifty in literature). The eyelids are more frequently invaded by sarcomatous growths from the orbit and the surrounding tissues.

In the cases of primary sarcoma of the lid which have been observed, the patients were nearly all children. The tumors grew rapidly and soon infiltrated the whole tissue of the lid. The neoplasms were mostly of the round-cell type; in some instances, however, the growth belonged to the melanotic variety, and in still others it was composed of spindle cells, of cells of a myxomatous type, or of cells arranged in alveoli. The writer has once had occasion to see a pendulous spindle-cell sarcoma in a negro. The small tumor hung from the upper lid with a penduncle like a molluscum contagiosum, but it proved to be a spindle-cell sarcoma.

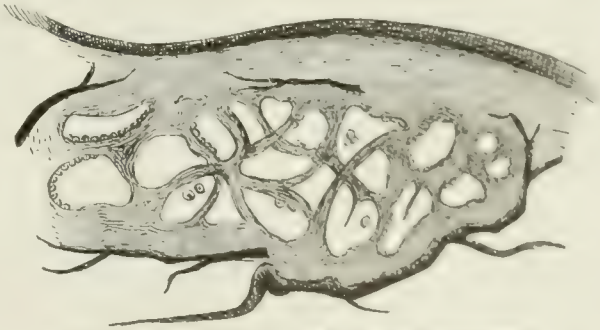


Fig. 2321.—Lymphangiectasis of the [illegible]

Of course, the danger to life due to sarcomatous growths makes their removal as [illegible] originate in the eyelid as when they develop in any other region of the body.

II. Tumors of the Conjunctiva. [illegible] *Tumors of the Conjunctiva.* [illegible] the conjunctiva appears [illegible] of small, roundish elevations, filled with a watery fluid, and often strung together like beads. These little

tumors give rise only very rarely to an inflammatory condition of the surrounding conjunctiva, and, as a rule, cause the patient no annoyance to speak of. When punctured they collapse, but are generally soon refilled. Their usual seat is the bulbar conjunctiva.

From the appearances presented under the microscope these tumors consist, undoubtedly, of distended lymph vessels. The little tumor is composed of a system of canals and cavities, which are in no way connected with the blood-vessels. The latter show the more plainly, as they are usually hyperemic. The cavities and canals just spoken of are separated from each other by trabeculæ of dense connective tissue, but they intercommunicate. The surrounding conjunctival tissue appears condensed and pressed aside. This system of canals contains a perfectly translucent serous fluid in which are suspended a number of lymphatic cells. The walls show here and there some traces of an endothelial coat (see Fig. 2321). The writer has had occasion to report a case of acute formation of hemorrhagic lymphangiectasia in an idiotic girl.

2. *Serous cysts* of the conjunctiva may undoubtedly result from what was originally simply a lymphangiectasia; the septa existing between the canals and cavities of such a tumor having gradually yielded to the pressure, and all the cavities having thus become united into one. But serous cysts have also been found in the conjunctiva at birth, and they may develop without being preceded by a typical lymphangiectasia, especially after injuries, or they may be due to the cystic degeneration of small glandular lobules situated in the fornix.

They appear as round or oblong or oval swellings in the conjunctiva, and, owing to the nature of their contents, they usually present a somewhat yellow tinge. They are not, as a rule, movable under the conjunctiva, but they may become large enough to annoy the patient, and must then be removed. They have a well-defined cyst wall, consisting of connective tissue, and are usually lined with one or two layers of endothelial cells.

3. *Teleangiectatic* tumors are also occasionally found in the conjunctiva of the lids and eyeball, and usually there is then, at the same time, a teleangiectatic tumor in the lid. Their histological structure is the same as that of other teleangiectatic tumors.

4. *Pinguicula* is a small roundish or oval tumor lying in the conjunctiva bulbi to the nasal, not infrequently, also, to the temporal side of the cornea. Its tissue consists in the main of elastic fibers. There is no fat in this little tumor as the old name seems to imply.

5. *Pterygium* is a triangular hypertrophic fold of the conjunctiva bulbi, usually situated at the nasal side of the eye with its base near the lacrimal caruncle, its apex growing for a shorter or longer distance into the corneal tissue. While its histogenesis is as yet not definitely settled, it undoubtedly springs in many instances from a pinguicula. If it is removed too late the resulting scar may interfere permanently with vision.

6. *Cavernous lymphoma* has been found a number of times in the conjunctiva bulbi, usually near the inner canthus. Although quite hard, this tumor appears semi-transparent, almost gelatinous. It is composed of numerous cavities separated from each other by a small amount of connective tissue and lined with an endothelial layer. The contents of the cavities are lymph containing a varying amount of lymphocytes.

7. *Granulomata*, commonly called polyps, of the conjunctiva are nowadays but rarely met with. They are red, softish nodules which project into the conjunctival sac; their mode of attachment to the conjunctiva being either by a broad base or by a slender peduncle. They are found chiefly near the inner canthus. They are due either to injuries or to chronic inflammatory affections of the conjunctiva, and may attain a considerable size, especially on phthisical eyeballs. Now and then they make their appearance at the site of tenotomy for strabismus.

Their structure is that of all granulomata. They consist mainly of newly formed round cells and small spindle cells, here and there intersected by connective-tissue trabeculæ. This tissue is often full of blood-vessels, and usually contains a number of cavities filled with serous fluid. In rare cases the tissue is found to be of a higher organization, the granuloma being changed into a fibroma.

8. What has been described as *lipoma* of the conjunctiva is a subconjunctival growth of fat tissue. In the few cases which have been described this kind of tumor was congenital, in some it increased in size in later life. The subconjunctival lipoma appears as a yellow, roundish, and soft swelling, usually consisting of several lobules. They seem to be generally situated between the external and the superior rectus muscles. They are sometimes multiple.

According to the descriptions given of their histological structure these tumors are very closely allied to the dermoid tumors; in some cases they are really dermoid growths with an excess of subcutaneous fat tissue. In one or two cases bone and fibrous tissue have been found in connection with such a fatty growth.

9. *Papilloma* of the conjunctiva has been found in a number of instances. The tumor, when seen, usually encroached upon the cornea, thus simulating a pterygium. Its histological examination alone revealed the true character. In one case reported by the writer, almost symmetrical papillomata developed in both eyes and, growing over the cornea, rendered the patient blind. Sometimes the lacrimal caruncle or the semilunar fold is the seat of a papilloma. Such papillomata, although not malignant, are very apt to recur, even after a thorough removal in the healthy tissue.

10. *Dermoid* tumors of the conjunctiva are always congenital tumors. Their seat is at the corneoscleral juncture, and very frequently they lie partly in the corneal and partly in the conjunctival tissue.

The tumor appears as a grayish or yellowish round elevation, about the size of a pea—sometimes, however, much larger. Where it ends in the corneal tissue it is usually surrounded by a zone of gray corneal tissue, not unlike an arcus senilis. Conjunctival blood-vessels may enter it. Its surface is usually smooth and shining, and it may be partially or totally covered with fine hair. Sometimes one or more of these hairs grow very long and protrude through the palpebral fissure. Such a tumor may remain stationary a whole lifetime and cause no greater annoyance than what may be due to the growth of the hair. In other cases some irritation causes the tumor and its surroundings to become inflamed, and then the tumor may begin to grow and invade the thus far healthy tissue of the cornea. In such a case, or from cosmetic reasons, the removal of a dermoid tumor may become necessary, and is, as will be seen from the histological conditions, easily accomplished.

The dermoid tumor, as its name indicates, consists essentially of the elements of the skin. It is covered by epithelium, the outer flattened cells of which are, however, not always horny, but often undergoing a retrogressive metamorphosis. This is probably due to the moisture in which the surface of the tumor is continuously bathed. There are also usually a number of mucous cells to be found in this layer. This epithelial coat is uneven, like the surface of the skin, and numerous offsets are sent into the depth surrounding the papillæ of the tumor. From almost all of these indentations one or two fine hairs spring forth, and here lie also the orifices of the acinous glands, which are usually found in these growths.

The connective tissue under the epithelium is very dense and fibrous. It contains elastic fibrillæ, and, as a rule, but few cellular elements, unless the tumor be in an inflammatory condition. The basis of the tumor, which is only very loosely connected with the episcleral tissue, is made up of fat tissue. Where the tumor lies on the corneal tissue, the union is usually a very firm one. These tumors contain a moderate number of blood-vessels, but it seems that they are but scantily supplied with nerves.

11. *True osteomata* of the conjunctiva have been observed in a small number of cases. The formation of bony tissue seems not to have been congenital. There appeared, in one case, a small tumor on the eyeball near the outer canthus, and it was removed on account of the annoyance which it caused. In another case the tumor had attained the size of a bean. The histological examination revealed true bone tissue.

12. The writer, on one occasion, removed from the eye of an infant a tumor which must be styled a *chondroadenoma* of the conjunctiva. This tumor sat on the bulbar conjunctiva with a broad base, was whitish in color, and presented a perfectly smooth surface. The parents had observed it at the time of the child's birth, and thought that it had been gradually growing since that time. Its size was about that of a split pea when the writer saw it. The histological examination revealed the fact that it consisted of a large cluster of glandular tubules, resembling somewhat in their arrangement those of the lacrimal gland, and a large, roundish piece of embryonic cartilage. These two kinds of tissue were separated from each other, and together they were surrounded by a dense connective tissue.

13. *Nevi* of the conjunctiva, mostly pigmented and situated on the conjunctiva bulbi, may be congenital tumors or develop later in life. By Unna and others, they are looked upon as epithelial tumors due to a pathological isolation of certain basal epithelial cells which, having broken through the basement membrane, grow into the depth of the tissue in a manner very similar to an epithelioma. Others, like Ribbert, maintain that the origin of these tumors lies in the connective tissue and that the overlying epithelium is but secondarily affected. The writer from his own studies inclines to Unna's view.

These apparently benign tumors, however, are not infrequently the starting point of malignant pigmented or non-pigmented tumors of the bulbar conjunctiva which may be epitheliomata or sarcomata and sometimes show a mixture of cells which makes it very difficult to place them rightly.

It has of late become almost the rule to remove the nevi for fear of their becoming malignant.

B. *Malignant Tumors of the Conjunctiva.*—1. *Sarcomata* of the conjunctiva are of rare occurrence. They are either unpigmented, or, what is more frequently the case, pigmented. These tumors take their origin almost invariably from the region where the conjunctiva bulbi joins the cornea, that is, from the episcleral tissue at the corneoscleral juncture, in rare cases from the loose tissue of the fornix. Their development has, in a number of cases, been ascribed to an injury.

The sarcomatous tumors of this region usually form roundish, sometimes lobulated swellings, which soon encroach upon the corneal tissue. They are very vascular, and bleed easily. They are usually of a rusty brown color, or they may even be almost black, at least in parts. Their surface appears smooth and shining, which is due to the fact that the growth for a long period remains covered by the conjunctival and corneal epithelium. Sometimes new nodules appear at some other point of the corneoscleral margin, occasionally at a point diametrically opposite the original tumor. In their further development these tumors may spread [illegible] and, from the dissemination of their [illegible], may ultimately result.

Histologically, the sarcomata of the conjunctiva are usually of the small round-celled variety. The original nodule, when growing on [illegible] spreads for a time between the [illegible] and Bowman's layer, in the way [illegible] known to spread. Later on, [illegible] destroyed at the periphery, and the sarcomatous elements invade the corneal tissue proper (see Fig. 2322). Yet the resistance of Bowman's layer is so great that the tumor will now spread underneath this layer into the cornea. In rarer cases the elements of the sarcoma are spindle cells. The pigmentation of the cells varies considerably in one and the same tumor. The more superficial parts are, however, usually the least pigmented ones. There is but very little intercellular substance. The large quantity of blood-vessels which these tumors usually contain has already been mentioned. There are always signs of former hemorrhages, and usually evidences of recent ones are to be found. In the propagation of these tumors the blood-vessels seem to play an important rôle, as they are sometimes found to be filled with pigmented molecules and pigmented cells. The periphery of these tumors is formed by a well-pronounced zone of inflammation.

2. *Epitheliomata* of the conjunctiva are more often observed than any other kind of conjunctival tumors. Although they are seen more frequently in persons of an advanced age, they make their appearance also in young individuals. They are generally situated on the bulbar conjunctiva, and, like the sarcomatous

Fig. 2322. [illegible]

tumors, they most frequently start from a point near the corneoscleral juncture.

Their formation may begin with the development of a small phlyctenula-like nodule covered with hyperemic blood-vessels; usually a number of larger and distended blood-vessels going to this nodule may be seen in the scleral conjunctiva. The growth may for a long period remain stationary, or it may keep on increasing gradually in size, or upon some special irritation it may start to develop rapidly, and be accompanied by inflammatory symptoms, and sometimes by considerable pain. The tumor usually spreads upon the cornea, which it may gradually penetrate, and thus find an entrance into the interior of the eyeball. The pain and suffering usually force the patient to submit to the removal [illegible] any further spreading of the [illegible] has taken place. In its early stages the new formation may be removed from the eyeball without much difficulty, as this has [illegible] new formations. Such epithelial growths of the conjunctiva have sometimes [illegible] and have then been described as *melanocancroids*.

The epitheliomata of the conjunctiva, like those found in other parts of the body, originate in a hyperplasia of the pre-existing epithelium. Thus we find in the beginning the epithelial layer considerably thickened, the serrated cells very numerous and well pronounced. In some cases we find a layer of horny cells of considerable thickness. This original tumor is usually surrounded by a tissue which is hyperemic and infiltrated with round cells. When the tumor grows, epithelial-cell cylinders begin to dip into the underlying tissue and send off new branches. Gradually the new formation invades the cornea, this invasion being always preceded by the new formation of blood-vessels and by round-cell infiltration. Bowman's layer gives way, and the epithelial-cell cylinders spread into the corneal tissue proper. In the same way the epithelioma spreads into the sclerotic. Sometimes the surface of the tumor is ulcerated.

The epithelioma may spread into the interior of the eyeball. Thus it has been seen to invade the ciliary body and the choroid along an anterior ciliary artery, or the iris, after perforation of the cornea and anterior synechia had taken place. In some cases, the conditions seemed to warrant the assumption that the external tumor has spread to the interior of the eyeball by metastasis.

The earlier the operation is resorted to, the earlier is the removal of such tumors. This may be done successfully by means of either the knife or the galvano-cautery.

III. Tumors of the Cornea.—The cornea proper is the seat of primary tumors in very rare instances only. They are, in the vast majority of cases, conjunctival growths which have invaded the cornea and are, therefore, fully dealt with in section II (Tumors of the Conjunctiva). A fibroma and sarcoma have been described as such primary corneal tumors.

IV. Tumors of the Sclerotic.—The sclerotic, like the cornea, does not seem to be a field for primary new formations. Those which have been described as such probably belong to the conjunctival (episcleral) tumors, and have, therefore, been treated under II.

V. Tumors of the Iris.—A. *Benign Tumors of the Iris.*—1. *Simple granulomata* of the iris have sometimes been observed, and have a number of times been mentioned in the older ophthalmic literature. They were described as small, round, yellowish, or grayish swellings, which made their appearance usually in the lower half of the iris. Gradually such a tumor would grow until it reached Descemet's membrane, and finally it would lead to perforation of the cornea. This generally was followed by shrinkage of the eyeball and the formation of scar tissue.

Histologically, these tumors are found to consist of round cells, and to contain numerous giant cells ("myeloplaxes"). Such a structure is so similar to that of tubercles that some recent authors have described the simple granuloma of the iris as tuberculosis of the iris. It is certainly strange that, since we have learned what tumors may grow in the tissue of the iris in consequence of syphilis and tuberculosis, no further case of simple granuloma of the iris seems to have been observed.

2. A special kind of tumor has been observed, in a few instances, to spring from the iris; it is generally mentioned among the cases of granuloma. This is a very vascular swelling, from which on slight provocation the anterior chamber would be filled with arterial blood. I should suppose that in such a case we would have to deal with a *teleangiectatic* tumor, rather than with a granuloma. The writer has had occasion to report the histological results of the examination of two cases of iris tumor which had been diagnosed as sarcomata, but which proved to be vascular tumors. The one had the character of a capillary, the other of a venous angioma. The cases reported as granulomata of the iris, accompanied by more or less periodical hemorrhages, have probably been of a similar character. A case described as a "papilloma of the subepithelial tissue of the iris" undoubtedly also belonged to this class of nevi.

3. *Traumatic granuloma* of the iris is occasionally met with—in some cases after the corneal wound is perfectly healed, but in most cases after the iris has undergone a prolapse and is exposed to the air. In the former cases the granulation tissue was found to perforate the cornea, and cause perfect loss of sight in the same way as do malignant intraocular tumors. In the latter cases the tissue of the granuloma gradually becomes organized and forms scar tissue, and may thus bring about a spontaneous cure.

Such granulomata also consist of round cells and small spindle cells, and contain but little connective tissue and new-formed blood-vessels. Later on, the round cells gradually are changed into spindle cells, and finally we find a dense connective tissue containing but few cellular elements. The granulomata which start from a prolapsed portion of the iris are usually covered with epithelium.

4. *Melanoma* of the iris has occasionally been observed. It appears as a darker raised spot in the tissue of the iris, and it is, to say the least, as yet questionable whether what has been called melanoma was not in reality a melanosarcoma. The authors usually state that a benign melanoma may at any time assume a malignant sarcomatous character.

Such a melanoma is said to consist of a circumscribed accumulation of "stroma cells of the iris, the larger part of which are pigmented, have many offsets, and anastomose with each other. They pass without a sharp boundary into the neighboring tissue, and the remainder of the iris is normal." In a case reported by the writer and studied after depigmentation of the tissue, it was found that the melanoma which took up the whole thickness of the iris consisted of large round cells which came from the uveal layer and grew into the iris parenchyma. From this it appears that the melanoma is an epithelial nevus, like the conjunctival nevi.

5. *Cysts* of the iris have been observed in a large number of cases. They are either serous cysts or cysts filled with epithelial material—epidermoid (atheromatous) cysts.

Cystic formations in the iris, as a rule, develop only after an injury. They begin as small, round, yellowish, or grayish tumors. The yellowish color is more characteristic of the epidermoid character, while the grayish or grayish-white color seems to be that of the serous cysts. Such cysts gradually grow until they reach Descemet's membrane, and then may become firmly adherent to it. Oblique illumination will usually show at once whether the cyst contains serum or some other material, for in the former case the tumor will be plainly translucent. In some cases the presence and the growth of such a cyst seem to cause but little discomfort; in others, however, severe inflammatory symptoms make their appearance, and sight may be destroyed.

The manner in which the formation of such cysts takes place is as yet not absolutely settled. But from recent experiments, it seems that these cysts usually develop in small portions of epithelial tissue which have been forced into the iris by some previous injury; these parts enclosing organs which are apt to retain their contents and secretion. There can be no doubt, however, that in some cases serous cysts are formed, provided a fold of the iris becomes adherent to Descemet's membrane or to a wound canal in the cornea. The closure and subsequent expansion of iris crypts has also been mentioned as a possible cause for cystic formations.

The cyst walls have usually been found to consist of atrophied and attenuated iris tissue, lined with a layer of endothelial cells, and usually firmly adherent to the cornea. There is scarcely any pigment found

in the cyst walls. The contents of the serous cyst are a perfectly transparent fluid, while the contents of the epidermoid cysts correspond with those of other atheromatous cysts and sometimes contain hair.

B. *Malignant Tumors of the Iris.—Sarcomata* of the iris have been met with in comparatively few cases. They have been mostly pigmented, but in a few cases they were unpigmented, or at least only slightly pigmented.

These tumors of the iris seem to have originated mostly in the parenchyma of this membrane, and near its sphincter edge. When allowed to grow, the tumor slowly spreads over the iris, and at the same time presses against the cornea, which it finally perforates. During its development it causes increase of intraocular pressure and inflammatory attacks, with subsequent destruction of sight. Later on, it leads to metastases. The rule seems to be that these tumors grow on the anterior surface of the iris. The writer has in one instance seen a darkly pigmented sarcoma spring from the posterior surface of the iris near the pupillary margin, and, pressing the lens backward, spread into the interior of the eyeball. In its early stages sarcoma of the iris has been successfull removed by iridectomy; later on, the eyeball has to be sacrificed. Some observers believe that rather than remove the tumor the eye should be enucleated in every instance.

In the few cases which have been histologically examined the tumors were either pigmented round-cell sarcomata or sarcomata of the pigmented and unpigmented spindle-cell variety. They seem to take their origin from the parenchyma of the iris.

VI. Tumors of the Ciliary Body.—A. *Benign Tumors of the Ciliary Body.*—1. Up to the present time the writer has examined nine instances of *adenoma* of the ciliary body. These small tumors, which sprang from the pars ciliaris retinæ, were usually confined to one ciliary process, and seemed to cause no symptoms during life. Histologically, they consist of the cells of the pars ciliaris retinæ, arranged in double rows like glandular ducts, and these tubules form numerous convolutions. Between these tubules lies a coagulated amorphous substance. The tumors are surrounded by pigment epithelium. It is as yet not clear whether these adenomata are congenital or develop in later life. The term adenoma which for want of a better name was applied to these peculiar growths by the writer, is probably not correct. By others it has been claimed that these tumors are simply a senile change. Some of the writer's cases, however, disprove this opinion.

2. *Myoma* of the ciliary body has only once been observed and described. In this case a brownish-red tumor was found to press part of the iris against the posterior surface of the cornea and to protrude for some distance into the pupillary space. The tumor showed smooth elevations. There was increase of intraocular tension, and attacks of severe pain were complained of. The tumor grew slowly but continuously, and was considered to be a sarcoma. Finally, the patient consented to the enucleation of the eyeball. The tumor was found to have the size of a filbert, and to be firmly attached to the ciliary muscle. When divided it presented a cut surface of a roseate color, and it was only slightly pigmented in the peripheral parts. On microscopical examination it was found to consist almost exclusively of nonstriated muscular fibers.

3. A *cyst* of the ciliary body has also been observed and described in a few instances, but these cases have not yet come to be examined microscopically. The cystoid formation followed an injury to the lid and eyeball. The cysts are described as oval bodies lying just behind the lens, springing from the ciliary region, and reaching with the larger end half-way across the eye into the vitreous. By oblique illumination the edge of such a cyst looks white, and can be clearly defined. Its [illegible] pigment deposit. By [illegible] ophthalmoscope the [illegible] parent, and the [illegible] may be dimly recognized [illegible] contain blood. [illegible] grow slowly, and to [illegible] ocular tension.

B. *Malignant Tumors of the [illegible]*. [illegible] leucosarcoma and melanosarcoma [illegible] in the ciliary body, but are comparatively rarely seen at a time when their [illegible] and yet more rarely [illegible]. Moreover, these forms of [illegible] would distinguish them from the [illegible] of the choroid, and they are, therefore, best considered under that head (VII., B). Of late [illegible] instances, carcinomata of the [illegible] reported. They are described as having sprung from the pigment layer, more especially from the so-called glands of the ciliary body (Collins). This matter, however, needs further investigation.

VII. Tumors of the Choroid.—A. *Benign Tumors of the Choroid.*—1. *Granuloma of the [illegible]* times found in the course of histological examinations. Whether it has even been clinically diagnosticated the writer does not know. In literature, no mention is made of such a diagnosis.

In eyes in which the choroid has been injured (through the sclerotic), or in which round-cell accumulations have, after the manner of abscesses, perforated the lamina vitrea of the choroid, we find occasionally a small tumor consisting of granulation tissue, i.e. of free nuclei, round cells and small spindle cells, and newly formed blood-vessels. These tumors may either lift the retina from the choroid and thus cause a circumscribed detachment of the former membrane, or, they may pierce the retina also and protrude into the vitreous body. Later on, these granulation tumors are changed into connective tissue, and ultimately, after contraction has taken place, they form a simple scar.

There is one observation on record of the presence of small granulomata of the choroid in the eye of an individual who had long been suffering from "granular lids."

2. So far as I can learn, *cystoid* formations in the choroid have been seen only once, viz., by the writer, and then only in the course of the microscopical examination of an eye. They were found situated in the peripheral portions of this membrane, and formed a small number of round and oval cavities embedded in the parenchyma of the choroid. They had a membrana propria and were lined with [illegible]. As regards their structure they were probably composed of dilated lymph vessels. The tissue of the choroid, which was displaced by these cystoid formations, was infiltrated with round cells and hyperemic.

B. *Malignant Tumors of the [illegible]*. The [illegible] form of primary malignant tumor found in the choroid (and ciliary body) is probably that of the sarcoma in some one of its numerous varieties.

Since sarcoma of the choroid and ciliary body is undoubtedly the kind of intraocular tumor most frequently met with, we will give it a more extensive consideration, the more so as its clinical development is typical for that of all malignant intraocular tumors. It happens but comparatively seldom that we have occasion to see and diagnosticate a choroidal sarcoma, and afterward to verify our diagnosis by a microscopical examination of the [illegible] usually described as the first one in its development. At this stage the patient usually complains only of a diminution of sight. If the tumor springs from the ciliary region it can usually be recognized by the protrusion of the iris, and be seen under oblique light. The diagnosis is more difficult when the tumor is situated more centrally, or, as is frequently the case,

near the optic-nerve entrance. The difficulty may be considerably increased if the retina at the site of the choroidal tumor has become detached. This seems, however, to be less frequently the case than was formerly stated by the authors. At this stage the ophthalmoscope may reveal one larger-sized, roundish elevation in some part of the background of the eye, or a flat elevation with a smooth or undulating surface covered by the retina, whose blood-vessels appear accordingly distorted in their course. The pigment of the sarcoma may perhaps be seen through the retina; even in cases in which the retina at the site of the tumor is detached, it may be possible to recognize the latter through the retina with the aid of strong illumination and a high magnifying power. In most cases, however, it will be necessary to make repeated examinations of the fundus throughout a considerable period of time, in order to be able to determine whether there is any change in the picture and whether the supposed tumor increases in size. If an apparent detachment of the retina lying in the upper half of the eyeball, or to one side, remains confined to its original seat, and if the lower half of the retina does not become involved, the condition should be considered very suspicious of the presence of a choroidal sarcoma.

The growth of a choroidal sarcoma may vary considerably as to rapidity. While some reach the second period in, say, one year, others may take a number of years to reach the same stage.

The second period in the development of a choroidal sarcoma is characterized usually by an increase of the intraocular tension to a varying degree (glaucomatous stage), combined with inflammatory attacks and often severe pain. In some cases glaucomatous symptoms are wanting. In this period the tumor fills the vitreous chamber more and more, and pushes the retina, the condensed vitreous body, the usually cataractous crystalline lens, and the iris toward the cornea. Or it spreads through the whole uveal tract, forming, so to speak, a sarcomatous shell which encloses the retina, the condensed vitreous body, and the cataractous crystalline lens. In this period the eye usually shows, externally, the signs of a chronic inflammation.

The third period in the development of a choroidal sarcoma is usually called that of perforation and the spreading of the tumor outside of the eyeball. Thus the elements of the tumor usually grow through the sclerotic, along, or even by way of, a blood-vessel (venæ vorticosæ, anterior ciliary arteries, etc.), or through the channel of a ciliary nerve, or, what is quite often the case, when the tumor originates near the optic nerve, by way of this nerve or its sheaths, or by way of the intravaginal space. In other cases, the tumor will cause a staphyloma-like distention of the anterior parts of the sclerotic or of the cornea, and cause a rupture there. In this case the lens is usually expelled from the eye, and the tumor, no longer restrained in its growth by a resistant capsule, grows rapidly outward until the lids can no longer be closed over it.

At the same time dissemination of the elements of the tumor has usually taken place. Such elements taken up into blood-vessels are carried away by the current of the blood, and, wherever they are deposited, new (metastatic) tumors are formed, which ultimately cause the death of the patient. The organs which are usually attacked by such metastatic tumors are chiefly the liver, the lungs, pleura, intestines, kidneys, spleen, brain, etc.

In very rare cases sarcoma has been found to attack both eyes of the patient.

The development of sarcoma of the choroid is usually observed at an advanced age, yet it has also been found in very young individuals. It seems to be somewhat more frequent in males than in females. In a considerable number of cases its development may rightly be attributed to an injury.

Histologically, we find the choroidal sarcoma to be more frequently pigmented than unpigmented. The pigmentation varies considerably, however, even in one and the same tumor, and may be situated within the tumor cells, or lie to a large extent outside of them in the stroma. The pigment is either derived from the pre-existing chromatophores, both of connective tissue or epithelial cells, or to hemorrhages which frequently take place into the tumor tissue. The elements of the tumor are either round cells or spindle cells. The spindle cells seem to be prevalent in the unpigmented sarcomata. The round cells of the pigmented sarcomata (melanosarcomata) are usually very large. The round-cell sarcomata are mostly very vascular. The spindle-cell sarcomata have generally but few blood-vessels, and in certain respects

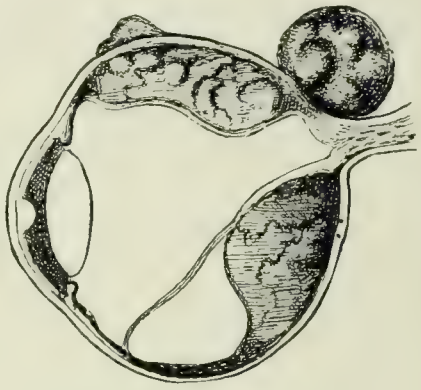


Fig. 2323.—Sarcoma of the Choroid.

they present rather the characteristics of a fibroma. They also seem to grow more slowly than the round-cell sarcomata. In rare cases the sarcoma shows an alveolar arrangement.

The sarcomata of the choroid may take their origin from the different layers of the choroidal parenchyma. The statement has been made, and its correctness has been denied, that the unpigmented spindle-cell sarcomata spring usually from the outer layers of the choroid. The writer is satisfied that this is the correct view, and that the pigmented sarcomata, especially the darkly pigmented ones, spring as a rule from the inner layers of the choroid. They get their darkest pigment from the broken-up cells of the pigment epithelium, and lighter pigment from hemorrhages. Sarcomata starting from the outer layers of the choroid may remain perfectly unpigmented, and grow to quite a size, until by the final perforation of the lamina vitrea of the choroid, and the subsequent breaking up of the pigment epithelium, a large quantity of pigment molecules is set free, and then only does the tumor become to some extent pigmented. Before this happens the pigment epithelium is usually found in a state of proliferation.

Occasionally there may be more than one primary sarcoma nodule in the choroid of one eye. From the primary nodule the sarcoma spreads in the choroid in the following manner:

When the elements of the original tumor have perforated the lamina vitrea of the choroid, detachment of the retina may take place, or the retina may remain in contact with the inner surface of the tumor and become firmly adherent to it. Sometimes the tumor, when situated close to the optic-nerve entrance, breaks at an early stage through the retina. The choroid surrounding the tumor, which at first may appear normal, or hyperemic and slightly infiltrated, is gradually invaded by the elements of the tumor. This invasion takes place at first in the outer (venous)

layers. In these cases the growth of the tumor is a more diffuse one. In other cases metastatic nodules are formed in other regions of the choroid, at some distance from the primary nodule. Gradually the elements of the tumor reach the lamina suprachoroidea, and the tumor soon adheres to the sclerotic. This union is sooner or later followed by the perforation of the sclerotic and the growth of secondary nodules on the outer surface of the eyeball. As stated before, this perforation of the sclerotic takes place along a pre-existing canal (nerve or blood-vessel) in the sclerotic. In rarer cases the cornea is perforated by ulceration, and thus the tumor spreads outside the eyeball. On the other hand, the tumor may spread backward by way of the optic nerve. This happens in one of the following ways: the elements of the tumor may invade the substance of the nerve itself, or they may enter into the porus opticus along the central blood-vessels, or they may invade the intravaginal spaces of the optic-nerve sheath. The glaucomatous symptoms, which are observed in most cases of choroidal sarcoma, are due to the pressure exerted by the growth.

The sarcoma of the choroid is sometimes found to contain deposits of amorphous lime.

In rare cases osseous tissue is found to have been developed within the sarcoma (osteosarcoma).

Chondromatous tissue is also sometimes found (chondrosarcoma). It usually appears in the shape of round or oval islets, which are generally surrounded by a tough connective-tissue capsule, and lie near or around a larger blood-vessel.

In a few of the cases observed the sarcoma was a cystic sarcoma, and in another small number it was an alveolar sarcoma.

The spindle-cell sarcomata are, as a rule, hard and tough, while the round-cell sarcomata are softer, sometimes even semi-fluid.

In a number of cases the sarcomata were of an endothelial character, springing apparently from the endothelia of the adventitia of the blood-vessel walls. Such tumors have received the names of angiosarcoma or perithelioma.

In rather rare cases the sarcoma instead of forming large nodules protruding into the interior of the eyeball grows along the sclerotic as a flat tumor interposed between retina and sclera, the so-called flat sarcoma.

In a few cases metastatic carcinoma has been seen in the choroid of women, the primary growth having its seat usually in the mamma. In a man the seat of the primary tumor was in the lungs and pleura. In one case a metastatic sarcoma was found in the choroid.

From the foregoing it is evident that, as soon as the diagnosis of choroidal sarcoma is made, the eye should be removed, as it is impossible to state when the tumor will spread outside the capsule of the eyeball, although this usually takes place only at a late period.

VIII. Tumors of the Retina.—A. *Benign Tumors of the Retina.—Teleangiectatic tumors* and small *fibromatous tumors* have been occasionally found in eyes examined anatomically, but they do not seem to have ever been observed during life, nor are they of any importance.

B. *Malignant Tumors of the Retina.*—The only malignant tumor observed to take its origin from the retinal tissue is the *glioma* of the retina.

Glioma of the retina (fungus hematodes) is essentially a disease of childhood; the oldest patient in whom it was undoubtedly observed was but twelve years old. It is probably, in most cases, a congenital affection.

As with the sarcoma of the choroid, we may divide the clinical history of the development of a glioma into three periods.

In the first period the growth causes but slight outward symptoms, and its existence at this period is but seldom discovered. The [illegible] account of which the parents [illegible] examination, are usually [illegible] sight and the observation of a [illegible] yellowish-red reflex from the pupil [illegible] eye). In this stage the pupil [illegible] be dilated, probably from paralysis of the [illegible] iris.

The reflex from the background of the [illegible] first be visible only in certain parts [illegible] ophthalmoscope may reveal only a portion [illegible] retina, and the optic papilla may as yet be [illegible] Gradually the background of the eyeball is [illegible] more and more forward in the vitreous chamber, and it may now be possible to see different round nodules by the aid of oblique illumination. On the [illegible] face of this yellow nodular mass a number of [illegible] sels may be visible. Usually some whitish spots are

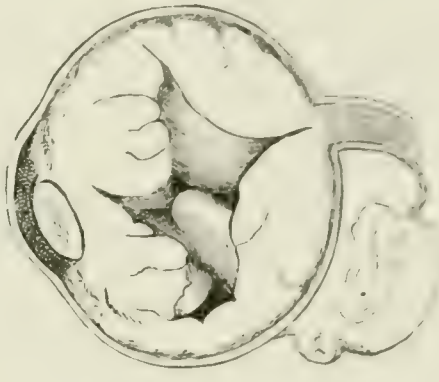


Fig. 2324.—Glioma of the Retina.

seen, which correspond to parts which have undergone fatty degeneration, or to deposits of lime. Finally, the whole of the vitreous chamber is filled, and the tumor reaches the crystalline lens and presses it forward. This is usually soon followed by the formation of cataract.

Before this stage is reached, as a rule, the second period has begun, which is characterized by an increased intraocular tension, pain, and inflammatory symptoms. The eyeball is now frequently ectatic in the equatorial region; there is iritis, and soon the cornea ulcerates and is perforated. The blood-vessels of the conjunctiva and episcleral tissue are hyperemic and tortuous. These symptoms are often combined with cerebral ones; there may also be fever and vomiting. The ulceration and perforation of the cornea, in rare cases, may be followed by the formation of scar tissue and shrinkage of the eyeball. Such cases have been described as cases of spontaneous healing of glioma; but even after a considerable period of latency the tumor makes its appearance again, and thus valuable time may have been lost.

The third period is that of perforation. The glioma grows outward usually after the perforation of the cornea—more rarely after perforation of the sclerotic. If it grows out through the cornea it increases very rapidly in size. The soft, easily bleeding, often partially necrosed tumor soon protrudes between the eyelids, and may in a short time attain an enormous size.

When the tumor has spread through the sclerotic before the cornea has been perforated, the episcleral tumor or tumors may cause a considerable degree of exophthalmus. The tumor may furthermore invade

the optic nerve and thus grow backward toward the chiasma.

Usually during this period secondary tumors are formed in the lymphatic glands of the face, in the parotid or submaxillary glands, in the bones of the skull, in the brain, in the liver, and in other organs.

Death follows from exhaustion.

In the older literature rather numerous instances of spontaneous cures of glioma are to be found. They have in modern times been discredited. Yet, there are a few cases on record, and the writer has examined one, in which an apparent partial cure, at least, resulted from calcareous degeneration of the glioma cells accompanied by the shrinking of the eyeball. It is, of course, still doubtful whether such an eye can be considered as cured, as there are usually nests of apparently live glioma cells still to be found.

In a large proportion of the cases (eighteen per cent.) glioma of the retina attacks both eyes. The affection of the second eye seems, however, not to be due to an infection from the one first attacked. Frequently several children of one family suffer from this new formation. It seems that it is more frequently found in males than in females.

The writer has reported one case in which glioma of one eye gave rise to sympathetic disease in the fellow eye.

In a few cases purulent choroiditis, with purulent hyalitis (pseudoglioma), has been confounded with true glioma. In such cases, however, the intraocular tension is, as a rule, reduced, and pain seems to be wanting. Moreover, the eyeball appears rather shrunken than distended, as it does in a case of true glioma.

The opinion formerly held by the writer, in common with numerous authors, that histologically considered the glioma (or gliosarcoma) of the retina must be counted among the small round-cell (medullary) sarcomata seems no longer tenable, since the characteristic "spider cells" of the glia have by Golgi's and Ramon y Cajal's process been demonstrated in glioma tissue. Besides these characteristic glia cells the elements of the tumor are round cells, smaller or larger than white blood cells, or identical with them. Sometimes these cells have small offsets. Between them we find free nuclei and some spindle cells. There is a very small quantity of intracellular substance. The tumors are usually very vascular, and their blood-vessels are very wide. The cells seem to be very prone to degenerate. Rosettes, formed by undeveloped and misplaced rods and cones, have been given of late an undue importance in the histology of glioma. In the opinion of the writer they are purely accidental formations. Tumors in which they were found have of late been called neuroepitheliomata, these cells belonging to the so-called neuroepithelium of the retina.

The tumor usually takes its origin from the outer retinal layers, especially the granular layers; in rarer cases its primary seat is in the inner layers, especially the nerve-fiber layer. In some cases it appears as if the whole thickness of the retina had been primarily affected, and, in fact, the tumor may take its origin from the connective tissue of all the layers of the retina.

As already stated, the glioma cells are apt to undergo fatty degeneration, and deposits of lime are often found in these tumors.

When the tumor starts from the outer layers (*glioma exophytum*), the retina in its neighborhood soon becomes detached and is pressed toward the axis of the eyeball. In these cases the inner layers of the retina may remain intact for a long time. On the other hand, when the tumor has started from the inner layers (*glioma endophytum*), the rods and cones may be preserved for a long period. The tumor gradually spreads all over the retina, and enters the choroid either simply by continuous growth or by infection (metastasis). During the growth of the tumor, parenchymatous hemorrhages frequently take place within it. Later on, the tumor may spread into the ciliary body and the iris, and we may thus find an eyeball filled perfectly by glioma, and but few traces of its former structures left.

At a comparatively early period, usually, the elements of the tumor invade the substance of the optic nerve.

The perforation of the sclerotic, and the formation of secondary tumors outside of it, generally take place along a pre-formed channel (nerve or blood-vessels), as we have seen it take place in the development of the sarcoma of the choroid.

Glioma is known to be preeminently a malignant growth; therefore the removal of the eyeball, or even of the whole orbital contents, is necessary at the earliest possible period. In this way the life of the patient has been saved in a number of cases.

IX. Tumors of the Optic Nerve (Orbital Portion).—The tumors of the orbital portion of the optic nerve have a number of symptoms in common, whatever the nature of the growth may be, the chief ones of which are loss of sight and exophthalmus. The latter is often the first symptom to be observed. This exophthalmus is, as a rule, in a straight forward direction, yet there may also be a deviation in another direction, if the tumor should develop more rapidly to one side. The eyeball can usually be moved, but its movements are restricted in all directions; later on, they may be totally abolished. If the tumor is large enough to be palpated, it is found to move with the movements of the eyeball, and to be nowhere attached to the orbital walls. When it is small it cannot be felt. In a number of cases, the development of the tumor is attended with severe pain; in most cases, however, this symptom is wanting. In all cases sight gradually fails. In the early stages the ophthalmoscope reveals optic neuritis; later on, we find white atrophy of the optic nerve. The rapidity with which sight is abolished varies considerably in the different cases, and this is, of course, due to the manner in which, in the given case, the nerve itself is constricted or invaded by the elements of the neoplasm. Thus, when the tumor originates in the outer sheath, sight will be preserved longer than when the new formation has its origin in the perineurium

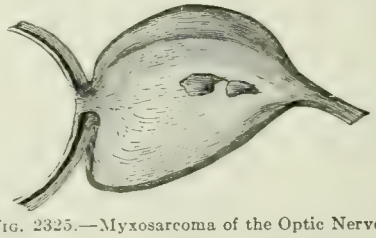


Fig. 2325.—Myxosarcoma of the Optic Nerve.

or the substance of the nerve itself. As the tumor grows and pushes the eyeball out of the orbital cavity, the cornea becomes less and less protected by the lids, and finally this membrane ulcerates and is perforated.

It seems that in most of the known cases the tumor with the eyeball, or the tumor alone, has been removed and a perfect cure has been obtained. From this it would appear that tumors of the optic nerve, *quoad vitam*, are not to be considered very malignant.

As regards the nature of the tumors of the orbital portion of the optic nerve they seem to be chiefly myxomatous (myxosarcomatous), gliomatous, or fibromatous; in some cases the tumors had to be interpreted as endotheliomatous (psammoma), and a few cases, described as cancers of the optic nerve, most probably belong to this latter class. In one

case the tumor was found to be a true neuroma. In a few cases the tumor has been described as being formed by a hypertrophy of the pia mater trabeculæ which hold the nerve-fiber strands in position.

Being enclosed within the space which is limited by the muscles of the eyeball, and the posterior aspect of the sclerotic, all of these tumors are more or less spindle-shaped (see Fig. 2064).

1. *Myxoma* or *myxosarcoma* of the optic nerve consists of spindle-shaped and stellated cells, with long offsets. These cells are usually packed more densely in the central parts of the tumor than in the peripheral ones. They are separated from each other by a hyaline intercellular substance. The cells often appear concentrically arranged, and thus form nests which resemble the pearl nodules of epitheliomatous neoplasms. These tumors are, furthermore, well provided with blood-vessels. The mucoid substance is often found to be accumulated in cysts of varying dimensions. Closely adherent to the new formation are the sheaths of the optic nerve, which form a capsule around it. Sometimes some traces of the optic nerve may yet be found in the center of the tumor.

2. *Glioma* (gliosarcoma) of the optic nerve shows the same elements as we find in cases of glioma of the retina, viz., round cells varying in size, cells with offsets, and spindle cells.

3. *Endothelioma* (psammoma) of the optic nerve consists of connective tissue, in the alveoli of which cells lie embedded in more or less concentric layers. These cells are large, flat, membrane-like bodies, somewhat thicker at the spot where the nucleus is situated. Their contours are not sharply defined, and some of them have long offsets. Giant cells are not wanting. These cells, the nature of which is that of endothelial cells, are often grouped concentrically around a round or oval shining body (arenoid body), from which these tumors have also received the name of psammoma.

4. In the only case of true *neuroma* of the optic nerve thus far described in literature, the whole egg-shaped tumor consisted of double-contoured as well as of non-medullated nerve fibers.

X. Tumors of the Orbit.—The chief symptom of orbital tumors, and the one which they all have in common, is exophthalmus—protrusion of the eyeball. This protrusion may, of course, take place in any direction, and we can only state, as a general rule, that it is in a direction opposite to the site of the tumor or to its greatest development. Usually the movements of the eye in the direction toward the tumor are impaired or abolished. While some orbital tumors cause a great deal of pain, others do not seem to cause any. According to the seat and size of the tumor, sight will be more or less impaired or totally destroyed, and we find accordingly, with the ophthalmoscope, simple anemia or optic neuritis or atrophy of the optic nerve either partial or total.

Orbital tumors do not seem to be apt to invade the optic nerve, or the eyeball, but they generally grow around it. On the other hand, tumors from the cavities adjacent to the orbit may and do invade this cavity. Such tumors have been found to come from the ethmoid cells, the nasopharynx, the frontal sinus, Highmore's antrum, and the sphenoid cavity, as well as from the cranial cavity. These growths are sarcomatous, endotheliomatous, or osseous in character.

As a rule, one may locate the tumor by palpation, and it is possible to distinguish one of orbital origin from a tumor of the optic nerve by its situation outside of the cone formed by the external muscles of the eyeball, and by its being in many cases adherent to the walls of the orbit. As the tumor (and consequently the exophthalmus) grows, the upper lid is dragged along, and it often continues to protect perfectly the cornea even after the eyeball goes [illegible] to an enormous degree. [illegible] condition which we call [illegible]

When the lid can no longer protect the cornea, ulcerations take place [illegible] of the cornea may be the result. According to the nature of the tumor it may [illegible] metastatic tumors to be [illegible] thus bring about the death of the individual. When the orbital tumor causes [illegible] detriment to the eyeball, Kroenlein's osteoplastic method should be employed.

A. *Benign Tumors of the Orbit.*—[illegible] have been designated, according to their [illegible] as hygroma, meliceris, oil [illegible] ous, hematomatous, or [illegible] all are probably congenital and *dermoid* in character, and owe their existence to faulty development during fetal life. This is the more probable, since some of the cysts have been found to contain a tooth, or hair, or other epithelial formations. In many of the cases the cysts were distinctly known to be [illegible] genital, and in another number they were observed in small children. There is usually but one cyst, although in some cases several have been found. Their size varies considerably. They lie mostly outside of the cone formed by the external muscles of the eyeball, and seem to be situated more frequently in the temporal parts of the orbit than in any other region. They may extend far back into the orbital cavity.

These tumors increase but slowly in size, unless stimulated to a more rapid development by an injury, and they do not give the patient much discomfort until they are large enough to cause exophthalmus and displacement of the eyeball, which is, of course, in the direction opposite to the growth. They now may generally be seen as bluish swellings in the lid (generally the upper one), and may even be directly demonstrated by eversion of the lids. It may be possible to detect fluctuation in the tumors, yet this can hardly be done with any degree of satisfaction, and it is therefore better to make sure of a correct diagnosis by the use of an aspirator.

Cysts of the orbit seem to be equally frequent in both sexes, and have mostly been observed in young people. In rarer cases the orbital cyst has been found to be connected with the nasal mucous membrane from which it had undoubtedly taken its origin.

2. *Angiomata* of the orbit are either cavernous or telangiectatic (erectile tumors).

α. The cavernous angioma of the orbit, which can attain a very considerable size, is either congenital or develops in later years. It is usually situated in or starts from the fat tissue within the cone formed by the external muscles of the eyeball. The tumor is often surrounded by a tough capsule of connective tissue. It may, as a rule, be seen as a bluish swelling under the skin of the lid, and from this similarity with orbital cysts mistakes in diagnosis have occasionally occurred. A characteristic symptom of the angioma is, however, that everything tending to hinder the reflux of the venous blood will cause a swelling and protrusion of the angioma; furthermore, the tumor may be compressed and emptied. The growth of the tumor is slow, and it is not apt to cause any pain. In rare cases a spontaneous cure has been observed. The removal of the tumor is practicable, and the more readily so the earlier it is undertaken.

β. The telangiectatic [illegible] usually found to be accompanied by similar tumors in the lids and neighboring tissues, and they also form soft, compressible swellings. This kind of angioma seems to grow more quickly than the cavernous angioma. It is desirable that the growth should be removed at an early period.

3. *Lipoma* of the [illegible] times. Yet it seems that in these cases the lipoma originally involved the eyelid.

4. *Enchondromatous tumors* of the orbit occur but rarely, if at all. The descriptions of such tumors thus far laid down in literature are, to say the least, doubtful.

5. *Osteoma* of the orbit has been often observed. It takes its origin from the diploë of the walls of the orbit. It is generally an ivory exostosis, sometimes partially spongy or cartilaginous. Its seat of predilection seems to be the upper inner wall of the orbit. In some cases osteoma has been found to develop symmetrically in both orbits of the same individual. These osteomata are usually round tumors, hard, and with a smooth or nodulated surface, and are mostly attached to the underlying bone by a broad basis. Their growth into the orbits may take place simultaneously with the growth of similar tumors into the neighboring cavities, or they may originally have started in one of the neighboring cavities and from there have grown into the orbital cavity. Their growth is most likely due to some faulty development during fetal life.

Such tumors grow very slowly; in some cases their development is accompanied by pain. They may cause exophthalmus with all its sequelæ. When superficial, they are easily recognized by their seat, and by their consistency and immobility. It has, however, happened that retention cysts pointing into the orbit from a neighboring cavity, have been mistaken for osteomata. The tumors under consideration may have to be removed on account of their danger to the eyeball and its functions. Their removal is sometimes comparatively easy, yet it may be attended with danger from subsequent meningitis.

Histologically these tumors are found to consist of bone tissue. In most cases this tissue was found to be extremely compact and to be almost bare of Haversian canals (ivory exostoses). In other cases they contained varying quantities of marrow.

6. *Lymphoma* and *lymphadenoma* of the orbit have been described, but they took their origin probably not from the orbital tissue proper. Lymphangioma has also been found in the orbit.

7. Benign tumors consisting of striated muscular fibers and nerve fibers have in a few instances been removed from the orbit. The writer has seen a *rhabdomyoma* and a *myoneuroma* of the orbit.

B. *Malignant Tumors of the Orbit.*—1. *Cancer* of the orbit has been described as epithelioma, cancroid, adenoma, and adenocarcinoma. It seems, however, that such new formations do not take their origin from the orbital tissue, but, having originated in the tissue of the eyelids, the episcleral tissue, or the lacrimal gland, have gradually invaded the tissues of the orbit. It is, therefore, not probable that a primary cancer of the orbital tissue has ever been observed.

2. *Sarcoma* of the orbit has frequently been observed and described. Its clinical diagnosis is extremely difficult, since we have but scanty means on hand wherewith to distinguish the nature of a tumor which has its seat in the deeper parts of the orbit except, perhaps, by transillumination. When the nature of the tumor is recognized, its removal with or without the simultaneous removal of the eyeball is, of course, imperative. Sarcomata have their origin usually in the orbital tissue. In a few cases the tumor had started in the brain and secondarily invaded the orbit. There are cases in which such an invasion takes place more or less symmetrically in both orbits.

A variety of forms of sarcoma have been described.

α. Cylindroma, a form of sarcoma characterized by a system of wide, anastomosing canals with larger cyst-like cavities filled with fluid, or gelatinous or fibrinous contents, has but very rarely been found in the orbital tissue.

β. Myxosarcoma of the orbit has been observed in about a dozen cases. These tumors were seen more frequently in children and young individuals than in older ones. In some their growth was a very rapid one, and in some it was accompanied by severe pain. The tumors consisted of long spindle and stellate cells, with a mucoid intercellular substance.

γ. Round-cell and *spindle-cell* sarcomata are the most frequent ones among the orbital sarcomata. In some cases they have been called melanotic, yet, the orbital tissue as such contains no pigmented cells. Such tumors, therefore, must have derived their pigment from other sources, as the conjunctiva or eye-lids.

The writer has had occassion to examine a case in which the orbital tumor was of endothelial character, a typical perithelioma.

δ. Osteosarcoma of the orbit always springs from the bony walls of this cavity. It seems to spring most often from the inner upper part of the orbital wall. It is usually a small round-cell or spindle-cell sarcoma, with spicula of bone tissue embedded in it. These spicula of bone tissue may be very numerous, and make the tumor appear very hard to the touch.

ε. The writer has recently examined and reported the case of an orbital tumor, which was situated over the nasal wall of the orbit and which proved to be a *myofibrosarcoma.* The elements of which it consisted were very numerous unstriped muscular fibers and bands of denser fibrous tissue; in some parts giant cells and spicula of bone were situated.

3. Another form of malignant growth found in the orbit is that known as *chloroma.* It consists of small round cells undergoing a peculiar fatty degeneration accompanied by a greenish-brown color. It springs from the periosteum. Probably it is also a sarcoma.

XI. Tumors of the Lacrimal Gland.—The tumors of the lacrimal gland may be diagnosticated by their situation in the outer upper part of the orbit, and by the consequent exophthalmus inward and downward (at least at the beginning of the development). These tumors generally grow but slowly. Gradually they cause a bulging of the upper eyelid, most marked near the outer canthus, and it is, as a rule, now possible to palpate the tumor, or even to see it protruding into the conjunctival sac, pushing the upper fornix downward. By palpation a tough, lobulated swelling is felt, which may be slightly movable; in most cases, however, it is immovable. When the tumor grows it often fills the posterior parts of the orbit, and thus it may cause the exophthalmus to change its direction, and when the tumor has filled the apex of the orbit altogether, and has grown around the optic nerve (which tumors of the lacrimal gland never seem to invade), the eye may stand straight forward, as if there were a tumor of the optic nerve. For this reason the movements of the eyeball, which at first are restricted only in an upward and outward direction, may become, later on, restricted in other directions too, and even finally be totally abolished. If the tumor grows still further, ulcerations of the cornea, etc., may take place. During the development of such a growth, the optic nerve is, of course, considerably pressed upon and stretched, and accordingly we find it anemic, or swollen and inflamed (optic neuritis), or atrophied. From the state of nutrition in which the nerve is when the tumor is removed, it will depend how far sight may be recovered. This removal may frequently be accomplished without sacrificing the eyeball.

Tumors of the lacrimal gland are usually observed in individuals of an advanced age, and their origin is sometimes attributed to an injury. Sometimes the lacrimal glands of both orbits in one individual have been found to be similarly affected. The tumor may, by entering the cavity of the brain and the brain substance, cause the death of the patient.

Various forms of tumors of the lacrimal gland have been observed, but opinions differ very considerably with regard to what may be considered a tumor of the lacrimal gland and what not.

The writer has seen and examined the following forms of tumors, which unquestionably took their origin from the lacrimal gland.

1. *Adenoma* of the lacrimal gland shows the typical picture of an epithelial neoplasm. Epithelial-cell cylinders, which compose the bulk of the tumor, lie embedded in a small quantity of connective tissue. The cells of every one of these cell cylinders are arranged around a central canal, which in some cases is very considerably enlarged by a transparent fluid. The cell cylinders are made up of one layer of polyhedral, almost cuboid epithelial cells, and have a

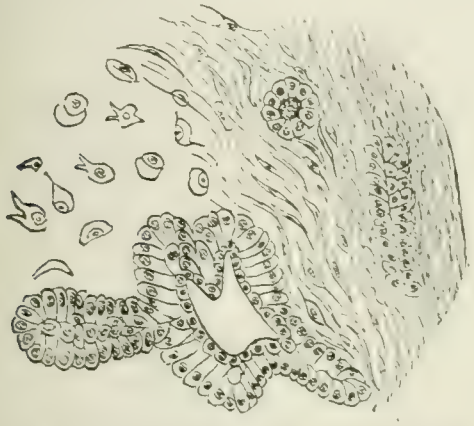


Fig. 2326.—Enchondroma Myxomatodes Carcinomatodes of the Lacrimal Gland.

distinct membrana propria. The lacrimal gland has also, in a number of instances been the seat of *adenocarcinoma*, of *lymphoma*, and of *lymphadenoma*.

2. *Myxoma* and *myxosarcoma* of the lacrimal gland are characterized by the development of spindle cells with long offsets, and stellate cells embedded in a mucous intercellular substance, and by the gradual disappearance of the glandular structure. This kind of tumor of the lacrimal gland is, however, but seldom observed alone. It is more frequently the case that the glandular tissue does not disappear, but, instead, an atypical growth of tissue takes place, at least in some parts of the tumor, and thus gives to it the character of an adenocarcinoma. In some cases we find, moreover, besides these two kinds of new formations a number of islets of hyaline cartilage tissue. Thus, instead of a simple myxoma or myxosarcoma of the lacrimal gland, we have then a myxoma carcinomatodes, or a myxoma carcinomatodes chondromatodes. In other cases the hyaline cartilage may be the prevailing tissue; in which case we would have to call the tumor an enchondroma myxomatodes carcinomatodes.

3. *Spindle-cell sarcoma* of the lacrimal gland has been described by a number of writers. In one of my own cases the tumor developed quite rapidly, and consists of densely packed spindle cells in its older portion. The younger portions of the tumor showed round cells and small spindle cells. Not a trace of glandular tissue was found.

4. *In lymphosarcoma* of the lacrimal gland the bulk of the tumor consists of densely packed lymphatic cells with hardly any intercellular substance.

5. *Epithelioma* of the lacrimal gland is formed when an atypical growth of the epithelial elements of the glandular tissue takes place. We find, then, instead of the glandular apparatus, solid epithelial-cell cylinders and nests of epithelial cells. This form of growth seems, however, generally to be combined with the development of myxomatous tissue in the lacrimal gland. The cases described as epithelioma of the lacrimal gland should probably with more correctness be regarded as cases of adenocarcinoma.

6. In the older [illegible] number of cases of [illegible] gland, or its ducts, [illegible] These cysts grew very [illegible] on account of their [illegible] eyeball. It is not known [illegible] lacrimal gland is likely to [illegible]

XII. Tumors of the Lacrimal Caruncle.—The lacrimal caruncle is sometimes the seat of [illegible] formation. Thus, congenital dermoid tumors have been observed in this region. Papillomata are not rare.

In advanced life the caruncle may become the seat of epitheliomatous new formations as well as of sarcoma. The latter kind of tumors are usually pigmented. The development of these tumors is almost always attributed to an injury.

XIII. Tumors of the Lacrimal Drainage Apparatus.—In rare cases small *granulomata* (polyps) have been found in the lacrimal sac, and even in the lacrimal canaliculus. It is obvious that such little tumors may gain some clinical importance by the stoppage of the canals through which the tears ought to be carried off. Their formation is due to chronic inflammatory conditions of the mucous membrane of these channels.

Adolf Atl.

Eyeball, Enucleation and Evisceration of the.—The removal of an eye is always a matter of serious moment. The fact that the unbroken globe may be so easily and quickly taken from the orbit increases the responsibility of the surgeon in his determination as to the necessity, the time, and the method of its removal.

The conditions making necessary the removal of the eyeball are those in which its usefulness for visual purposes has been destroyed, and in which it is either unsightly, painful, obstructing the removal of orbital growths, the excision of which is essential for preservation of the life or the comfort of the patient, or in which its retention would jeopardize the well-being of the fellow-eye, as in sympathetic ophthalmia. The most common cause is its serious injury as the result of accident.

The most usual forms of accident are those following a blow—as from the fist—from striking the ball against a projecting substance either from inattention or in the dark, from a cut, from a knife-blade or other substance, from destruction of the cornea from explosions or burns, or from the entrance into the globe of a foreign body, as a chip of metal or a fragment of stone.

While antiseptic measures and the modern method of the prompt transplantation of a conjunctival flap over the site of a penetrating wound even of considerable extent have been wonderfully successful in conserving eyeballs which would otherwise be lost, it is usually better surgery when the wound involves the lens with extensive loss of vitreous to remove the globe before reaction occurs.

Especially important is an early prognosis with the adoption of decisive surgical measures in the case of poor men whose living depends upon their daily labor. It is a disappointing and unhappy sequence after weeks of nursing of a hopelessly blinded eye to be obliged eventually to take it out.

Among the conditions that imperatively demand the complete removal of the eye are the presence of malignant growths, either in the eyeball or the orbit. In the former case, if the coats of the ball have not been broken, removal of the eye, with as large a piece of the optic nerve as it is possible to secure, may prevent deeper infection. If the growth has extended beyond the eyeball and involves the orbital tissues, exenteration, or the removal of the [illegible] all of the adnexa must be performed without consider-

ation of the resultant deformity, for in that case no artificial eye can subsequently be used. In adults when intraocular cancer is found it is usually sarcoma of the choroid. In children it is vitally important to recognize at an early period the presence of glioma of the retina. This is usually discernible at about the third or fourth year when a mass will be discovered to have gradually filled the vitreous until it can easily be detected by oblique illumination as a yellowish-white opacity back of the lens, on the surface of which an occasional blood-vessel may be seen giving the neoplasmic growth a slightly pinkish hue; as it increases the eyeball grows injected, hard and painful. Such eyes must be enucleated as soon as the diagnosis is made. There is no other resource and delay until the growth has broken through the scleral tissue means general infection with a horrible form of death. All eyes should be removed too in which remains an irrecoverable foreign body. Bits of wood, stone, emery, non-magnetic iron, copper, or other substance which cannot be secured, anywhere in the vitreous, especially when the entrance wound is in the neighborhood of the ciliary body, are sources of great danger in sympathetically affecting the fellow-eye. In cases of doubt it is wiser to remove one eye so injured than to risk the possible consequence, as a sympathetic uveitis once established almost inevitably leads to blindness. The powerful magnets now universally employed make possible the removal of fragments of iron and steel that could never be otherwise retrieved. It should be borne in mind, however, that the use of such a magnet is a highly skilled performance, and when large bits of metal are forcibly dragged through the vitreous, the lens and the iris, the traumatism inflicted is so great that it is wiser to remove the damaged globe rather than to hope to save what must at last be a sunken and atrophied ball after the protracted and destructive inflammation which must ensue.

After serious injuries, involving the eyeball, however, the determination as to whether the resultant wreck can be saved, or is worth the suffering which will follow the adoption of conservative measures is always a subject demanding the best judgment of the surgeon, based upon an understanding of the possible value of the retained stump, the pain and delay required in an attempt to save it, the possible failure after weeks of effort and the danger to the other eye from a useless and tender stump.

There is a difference of opinion among surgeons as to the advisability of the removing of an eye suffering from panophthalmitis while in a state of active inflammation. Usually the condition is dependent upon a pus infection of the cornea, or of an infected wound following an operation in which the globe has been opened.

This usually involves an extension of the pus from the anterior chamber into the vitreous. Meningitis or general septic infection has sometimes followed such conditions, but it is doubtful whether this would not have happened had the globe not been removed. When the ball becomes a mere pus sac it would certainly seem to be better surgery to remove it than to allow it to remain as a continued source of infection. The writer has frequently removed such eyes and under proper surgical precautions has never seen the slightest ill effects follow.

Eyes are not removed, however, simply because they have become painful or dangerous, the esthetic element must frequently be considered. After ulceration and rupture of the cornea, especially in ophthalmia neonatorum, the adherent iris pushes forward giving the deformed globe the unsightly and repulsive appearance of an anterior staphyloma.

Such sightless eyes are so disagreeable to look upon that the blind man who hopes to make his living among those who see, or more especially a young woman whose right it is to look as well as possible, is in many cases obliged to have such a deformity removed and replaced by an artificial eye, which will not repel those with whom she comes in contact.

Preparation of the Patient.—Having determined upon the removal of the eye, the consent of the patient or, if he is a minor, of his parents or guardians, should be secured. If an anesthetic is to be given in the search for a foreign body, or other operative procedure in which it may become necessary that an enucleation shall be performed, this should be fully explained in advance and full permission obtained to do whatever seems to be necessary in order that the surgeon may protect himself from legal claims for having exceeded the authority given him. Such experiences are by no means rare and are always to be guarded against.

The mental effect upon the patient must not be forgotten when he is told that he must lose an eye. This always seems to him more dreadful, and in some inexplicable way, more irrevocable than the mere loss of sight, serious as this must be, and the surgeon having in mind the simplicity of an enucleation cannot realize the dread inspired in the patient by the thought of having his eyeball taken from its socket. It seems much less serious to him if he can be assured that only the front of the eyeball is to be taken away, as in abscission of a staphyloma, or that the globe with its attached muscles is to be left intact as when evisceration is practised or when the vitreous is replaced by a glass or gold ball.

This fact should in no wise govern the decision of the surgeon as to the nature of the operation to be performed, but it should make him considerate and sympathetic in his manner of disclosing to the patient the conclusion to which he has arrived.

There are four methods of treating a diseased or deformed eyeball upon which operative measures have been determined. The projecting anterior part of the ball, if staphylomatous may be taken off, the eyeball may be removed entire, its contents may be eviscerated, the sac with attached muscles being left, or after emptying the globe a gold or glass ball may be inserted which becoming encysted will serve as a more effective support for the shell to be later employed.

The method of preparing a patient for an enucleation is much the same as that employed before any operation upon or within the globe.

Before any operation of importance is made upon the eye the physical condition of the patient should be ascertained. The action and freedom from organic disease of the heart or arteries, the condition of the kidneys, the blood pressure, should all be known as these may govern the choice of an anesthetic. The bowels should be moved the night before the operation. Before the patient is brought to the operating table he should be bathed, the region about the eye being scrubbed with green soap, the brow on the side to be operated should be shaved and the lashes of the upper lid closely trimmed. A sterile pad and bandage can then be applied and the patient brought to the operating room. A gauze mask is then put over the patient's face, an opening being cut for the eye, and the eye flushed with a solution of 1–3,000 bichloride of mercury.

The dressing tray should include in its furnishing a number of sponges of absorbent cotton wound on applicators or tooth picks. These may be dipped in a solution of boracic acid and squeezed between the folds of a towel. If the ends are then cut squarely off there is little opportunity for loose threads to be detached and the stick prevents the sponge from being seized by the wrong end. The application of a solution of adrenalin, 1–1,000, dropped on the eyeball will prevent excessive bleeding, a matter of some importance when there has been much previous inflammation. A spring speculum is then introduced

between the lids. If the globe has been broken and is collapsed a suture may be inserted in the wound to prevent its losing all shape. Sometimes it is desirable to inject warm normal salt solution in order to give it a little greater fullness. When the eyeball has the form of an empty bag it is always most difficult to avoid cutting the scleral tissue and thereby complicating the operation.

Abscission of Staphyloma.—The abscission of a large staphyloma is in practice equivalent to the removal of the eye because the resultant bulbus serves only as a support for the artificial shell to be employed later. Various methods have been adopted for the removal of the anterior portion of the globe some of which have been classic for over a century. Modern surgeons have come to realize that a method which leaves the uvea and vitreous as sources of danger and which has nothing to commend it over evisceration or removal of the entire globe as not to be considered. All of these methods are dropping, therefore, into deserved disrepute.

Enucleation.—Simple enucleation is followed by the least reaction of any of the measures employed for the removal of the eyeball. The ends to be attained are the clean removal of the globe, with the adnexa as little disturbed as possible. After the globe has been enucleated it is designed to leave the recti-muscle attachments in position on the capsule of Tenon. These on healing give a slight degree of motion to the stump so that the artificial eye loses something of the fixed stare that it would otherwise have. The objection to this method, simple as it is and easily as it is performed, is that it leaves an empty eye socket which it is impossible to fill with any artificial eye that can be used. When for any reason complete extirpation of the eyeball is necessary this operation may still be done. In the larger proportion of cases it has been superseded by one of the newer methods in which more satisfactory results are obtained.

Rubber gloves are worn by many surgeons but in operations about the eyes they so diminish the tactile sense and interfere with delicate manipulations that they are worn by the ophthalmic surgeon rarely, and then mostly in treatments and in the application of dressings.

Unlike some other operations within the globe the speculum to be employed is one which may be locked,

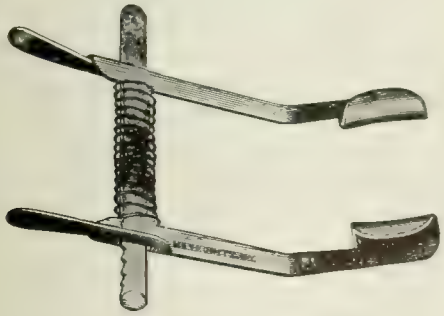


Fig. 2327.—Form of Speculum for Separating Lids.

the other instruments are a pair of fixation forceps, rather large blunt pointed curved scissors, strabismus hooks, and blunt heavy scissors curved on the flat for dividing the optic nerve. Sometimes a tenaculum may be employed to catch the eyeball and draw it downward. A blunt spoon, having a U-shaped slit is useful in localizing and holding the optic nerve while it is being divided. It makes an added instrument in the crowded orbital cavity and the experienced surgeon finds little occasion for its use. It is helpful

more easily reached. A ver[illegible] for cutting the optic nerve i[illegible] locked blade which [illegible] vents it from [illegible] while it is being [illegible] a form of [illegible] having a [illegible] lefts and greatly simplify the instrumentati[illegible]

Fig. 2328.—[illegible]

sary for the operation. By means of these scissors the eyeball may be hugged tightly, the curve adapting itself to that of the globe while the tendons are being divided after which with the same scissors the optic nerve is severed.

Unless the eye which is to be removed is [illegible] different from its fellow so that it may be recognized at a glance it should be definitely marked before the patient is put under the influence of the [illegible]

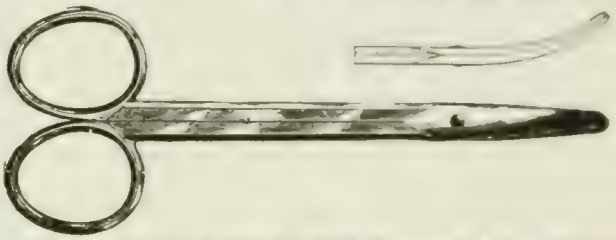


Fig. 2329.—Curved Scissors for Dividing Tendons [illegible] also be used for separating conjunctiva and [illegible]

so that by no possibility an error can be made and the wrong eye removed. This pathetic accident while happily exceedingly rare, has occurred in one instance at least, the eye in which sight remained being removed instead of the blind one. Usually the fact of the brow being shaved is a sufficient mark but nurses are sometimes careless and patients unintelligent, and the surgeon must himself be assured that in the preparations no mistake has been made.

While the globe is unbroken it is easily and quickly removed. The thickened tissue at the corneal limbus is grasped by the forceps and with the blunt

Fig. 2330.—Strabismus Hooks [illegible] before Dividing them.

pointed curved scissors an [illegible] the conjunctiva at the [illegible] carried around the entire cornea making what is termed the circumcorneal incision. It is essential that the scissors, as with all cutting [illegible] employed about the eye, be [illegible] Otherwise the blades will catch in the tissues and drag and tear them when they [illegible] section. The conjunctival [illegible] up over the globe as far [illegible]

This is easily accomplished unless there has been previous inflammation. The scissors should be kept as close as possible to the eyeball as in this way the largest amount of orbital tissue is left; there is less hemorrhage, and less likelihood of infection. There is little danger of cutting the sclera unless the globe is collapsed, if ordinary care and skill are employed.

By burrowing slightly through the conjunctival tissue an opening is made behind one of the recti muscles, the superior by preference, as the eye is likely to roll up. A strabismus hook is inserted under it and the tendon divided, the connective tissue is then separated and each of the remaining tendons divided in turn. The speculum may then be removed and the heavy curved scissors with which the optic nerve is to be cut slipped from the nasal side back of the globe. The ball is then easily forced from its orbital bed, between the lids, and the optic nerve placed upon a stretch, this then being the only attachment. The nerve is divided by a single clean cut of the scissors.

In the case of glioma or other cancerous growths of the eye the sections should be made as far back as possible. If this is not done with the first cut of the scissors the optic nerve sinks back into the orbit and it is retrieved only with great difficulty if at all. Most surgeons prefer to bring the edges of the mucous membrane together by means of a purse string suture after the hemorrhage has ceased. It readily falls in place, however, and the result is usually quite as satisfactory when this is not done. After bleeding has ceased aristol or some other antiseptic powder is

Fig. 2331.—Split Spoon for Holding the Optic Nerve before Separating it from the Eyeball.

dusted between the lids, and the eye dressed with a sterile pad held in position by adhesive straps. Very little pain follows this operation and healing is complete in two or three days.

Usually the bleeding is very easily controlled. The writer has, however, seen alarming hemorrhage follow this simple form of enucleation. The blood immediately fills up the orbit. If the flow does not quickly cease the orbit should be flushed with very hot water followed by sterile packing gauze firmly held for several minutes. Sometimes a secondary hemorrhage follows several hours after the operation. Styptics are not usually necessary, hot water and pressure being sufficient to control the flow.

Various other operations have been devised whereby the tendons of the muscles are seized by retention forceps before being divided and then brought together by finely tied sutures. The healing then is in a firm mass and is said to give a better and a more movable stump than in those cases in which simple enucleation has been performed.

When, however, any other operation than that of simple enucleation seems desirable there would appear to be but little question that evisceration with or without a substitute for the vitreous will prove preferable.

Evisceration or Extenteration of the Eyeball.—In panophthalmitis or other suppurative conditions of the globe it has been thought by some ophthalmologists safer to remove the anterior portion of the eyeball and after emptying the globe of its contents to leave the sac to form a stump for an artificial eye. In non-suppurative conditions in which operative intervention was undertaken for the correction of deformities the structures of the posterior chamber together with the iris were sometimes allowed to remain intact. If the dangerous ciliary zone remained, however, it was subject to infection with possible sympathetic involvement of the fellow-eye, and as the retention of the normal humor gave no better foundation for artificial support than in those cases in which the sac was allowed to collapse, and an artificial substitute for the vitreous introduced, this method of operation has been practically abandoned. Various methods have been devised when evisceration of the contents of the globe is performed, differing in detail, but practically based upon the idea of preserving intact the larger portion of the sclera together with its muscular attachments. In some instances the tendons of the recti muscles are gathered together in a purse-string suture and drawn together in a solid mass. The purpose of the operation is to leave so considerable a portion of tissue as to aid in filling in the otherwise emptied orbit and to prevent in some measure the sinking which follows upon the enucleation of the entire globe. The operation has been so severely criticised, however, as to be practically condemned because it not only fails in its purpose in that the stump of the sclera sinks in the orbit and atrophies in course of time but occasionally leaves a sensative bulb which ultimately must be extracted.

Fig. 2332.—Mules' Operation for Artificial Vitreous. A gold ball is inserted within the scleral cavity. Note the fulness of the orbit; the lid can be partially opened. In enucleation the orbital cavity is sunken.

Mules' Operation (for Artificial Vitreous).—The most satisfactory operation that has been devised from an esthetic point of view is that of Mules in which an artificial sphere is employed within the scleral globe in place of its normal contents. In this operation the cornea is removed as in evisceration, the ocular contents thoroughly evacuated under rigid asepsis and either the glass or gold ball inserted which in the event of the operation being successful becomes encapsulated and forms a firm and movable globe retaining the relative position and action of all of the

extrinsic ocular muscles and giving such freedom of movement to the well-adapted shell which is actually employed that it is often difficult to distinguish the operated from the unoperated eye. The advantages of this operation are so obvious and the benefits so great that unless serious and unanswerable objections can be raised concerning it it must be unquestionably the operation of predilection. It will be immediately noticeable, as shown in the accompanying photographs, that instead of a deep sunken orbit which follows an enucleation there is a fullness even before the introduction of the artificial eye. When the operation has

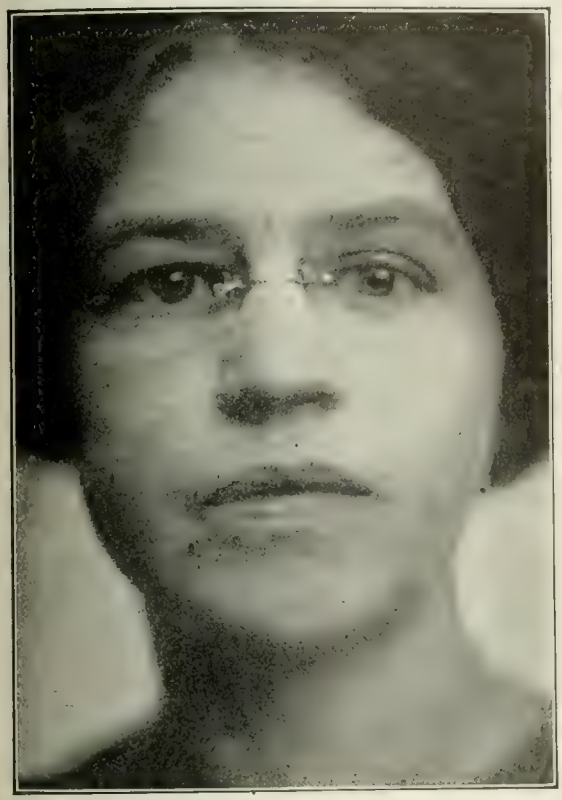


Fig. 2333.—Mules' Operation for Artificial Vitreous. The reform shell has a most natural appearance and free movement in all directions.

been perfectly performed there is no irritation whatsoever in the stump, and in the experience of the writer the introduced globe may be carried for an indefinite length of time without either being extruded or causing the slightest sense of irritation. In cases under the observation of the writer such globes have been carried for over twenty years with perfect comfort.

It is an unsettled question as to whether the enucleation of an eye in early childhood prevents the normal growth of the skull in the operated side. It often has been advanced that in the absence of the globe such an undeveloped condition results. There is very considerable doubt whether the form of the orbit is influenced in any appreciable measure by the retention of the eyeball. In a number of cases examined by the writer at the New York State School for the Blind in which enucleation had been made at various periods during childhood there were no differences that were distinguishable to the eye. Differences then which are not immediately obvious and which can be determined only by exact measurements are so inconsequent as to be unworthy of consideration; and in view of the fact that the two sides of the face are rarely alike in their development the existence of slight differences would be [illegible] of the eyeball on the growth of the [illegible] Should there be any such possible influence the presence of a non-irritating but [illegible] the scleral coat would prevent the [illegible]

The original suggestion made by Mules to [illegible] to use a hollow glass sphere. Objections [illegible] raised that the body fluids secreted [illegible] in course of time act upon the surface of the glass roughening it and causing its expulsion. This does not seem to have been verified in practice as shown in a number of cases in which glass balls have been satisfactorily carried for many years. To obviate this, however, other materials than glass have been suggested and used, such as a silver ball which has been gold-plated, an aluminum [illegible] mass of paraffin, wire balls and rubber balls, all have been recommended.

In those cases in which the ball has been expelled from the globe immediately after the operation or at a later date, either the ball was too large for the [illegible] of the globe or the inside of the sclera had not been absolutely freed from choroidal pigment. The cases especially desirable for this form of operation are those non-septic ones in which there is no present inflammatory action and in which it is possible to make an absolutely clean and empty scleral sac for the reception of the artificial vitreous. It is not safe to use this method when glioma or other form of cancer has been present nor when the rupture of the eyeball accompanied with active inflammation extends beyond the equator of the globe. The ball must be chosen with great care so that it easily fits within the emptied sclera. It must be neither too large nor too small. If too large its loss is inevitable as in the process of contraction of the globe in healing the stitches are torn out and the wound opened. Even when this happens if the patient is under observation there are no very serious consequences that follow this accident. The patient is still left with a good evisceration stump, which while not full as if the globe is retained, still serves as an excellent basis for an artificial eye. If the ball is too small the globe fits loosely and around it secretions are apt to form which may become infected through a secondary inflammatory process, cause the wound to open and the ball to be discharged. It is of first importance in emptying the scleral sac that every smallest particle of tissue other then the scleral coat be removed. This is not always an easy matter as when the ball is collapsed shreds of tissue are liable to lodge in the folds and to escape observation. With a tenaculum or fixation forceps by which the sclera is kept open it is possible by means of an evisceration scoop followed by pledgets of cotton upon an applicator to wipe out the inside of the eyeball until the clear white shining sclera is in evidence.

Fig. 2334. Sharp Pointed Scoops [illegible] ing the Eyeball in Evisceration.

The way in which the operation is performed is as follows: After the introduction of the speculum, and the proper antiseptic preparation of the eyeball, the conjunctiva is loosened from the scleral corneal margin back to the insertion of the recti tendons. The eyeball is then held in position by means of a pair of fixation forceps which grasp the thickened tissues at the corneal margin and a Graefe keratome introduced

in the middle of the circumference of the scleral corneal junction. A section then is made upward coming six or seven millimeters above the limbus of the cornea. A similar section is made downward. A triangular segment is then removed from the narrower portion of the oval opening thus created above and below. This will permit perfect coaptation of the sclera when the sutures are later introduced. The eyeball is then emptied of its contents by means of the evisceration scoop. Especial care will be taken to remove each particle of the ciliary body as well as the structures around the entrance of the optic nerve structures. Pieces of pigment and shreds of tissue can be picked out if necessary with forceps. The emptied globe may then be wiped out with pledgets of cotton and the whole irrigated with a 1–3,000 bichloride solution so that the interior is shown as a clean shiny surface.

Fig. 2335.—Introducer for Ball in Sclera.

It is well then to mop out the eyeball with a mixture of iodine and carbolic acid in a five-per-cent. solution. A special instrument is prepared for the introduction of the glass ball. This is called the introducer for the ball. Without this it is sometimes difficult to introduce the ball in the collapsed globe. If the ball is found to be too small or too large it can easily be removed with this instrument and another one inserted. The edges of the sclera are then brought together, carefully approximated and united by sutures of exceedingly fine black thread. As those sutures are not to be disturbed they should be of another color than those employed for retaining the conjunctiva. The sclera having been brought together in a vertical position the edges of the conjunctiva are approximated in a horizontal line so that the deeper wound is thereby protected. The eyeball is then again irrigated with a 1–3,000 bichloride solution to free it from all adherent particles, it is dried with cotton sponges and then dusted with aristol or some other equally efficacious iodine preparation. For the first twenty-four or forty-eight hours it is usually desirable to apply a cold ice pack as considerable

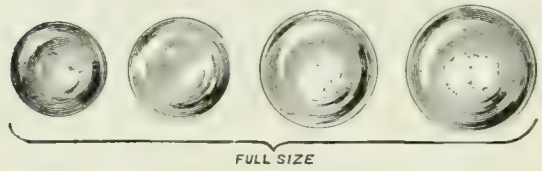


Fig. 2336. –Glass Balls of Various Sizes used in Mules' Operation.

reaction and pain are apt to follow. At the end of four or five days the superfluous white sutures may be removed when a firm but movable globe will be found in the orbit. In order to avoid any irritation which might follow too early disturbance of an eye upon which this operation has been performed it is well to wait for four or five weeks before attempting to introduce an artificial shell. When this is done the reformed or closed artificial shell devised by Snellen should always be employed and care must be exercised that it is not too large, or from its pressure or attrition upon the artificial globe it may excite undue irritation. After all inflammation has disappeared and with a well-chosen and perfectly fitting artificial eye there is no more discomfort experienced in the Mules' operation than when complete extirpation of the eyeball has been performed.

The most serious criticisms that have been made upon this operation have been those in which in exceptional cases sympathetic irritation has affected the fellow-eye. This is of such importance that if it were at all likely to occur no consideration of an esthetic character would justify the insertion of an artificial foreign body in the globe, but as in rare cases sympathetic infection has followed ordinary enucleation and evisceration and as a large number of Mules operations have been performed in which no irritation of any character whatever has followed it would seem reasonable to assume that individual conditions or something in the character of the operation was the cause, the possibility of foreign substances being left in the globe, of the ball being too large for the globe or some other questionable circumstance must be held accountable for this serious result. The necessity of examining the globe which is used with great care for the detection of flaws which may be in it must be emphasized; roughness or other imperfections might prejudice the result of the operation. In one case in which a ball was inserted and in which the wound did not heal a small hollow opening was found to be in the ball, in which was found a quantity of pus. The possible objections to the use of the glass ball within the sclera have led to various substitutes which have been tried with varying degrees of success. Spongue, which becomes organized, has been used. Fat taken from the gluteal region of the patient himself has also been employed. Other modifications of the Mules operation have been suggested and performed, such as the introduction of the glass ball after enucleation in the orbit itself instead of within the scleral cavity. This makes a very excellent basis for an artificial eye but it lacks the freedom of movement and the complete fulness as obtained by the Mules operation. The transplantation of the eye of a rabbit, or other animal, in the place of an enucleated human eye has been used in many cases with considerable success. In these cases the eye of a young rabbit is usually employed and is inserted into the orbit after the enucleation of the human eye in an inverted position, the cornea being directed toward the back of the orbit; the recti muscles are then attached to the corresponding muscles of the rabbit's globe and the conjunctiva is then closed. In some instances the cornea has been placed downward, the conjunctiva is then closely sutured and the stitches left in position for a week. The animal's eye becomes finally attached in its position but in a large number of instances it gradually shrinks and leaves a stump which is very little better than that which remains after an ordinary enucleation.

F. Park Lewis.

Eyelids, Affections of the.—The eyelids present two surfaces, both of which are subject to disease. The posterior, or under surface, *i.e.* the surface which is in contact with the eye, is covered with conjunctiva, and affections of this surface are described under this head. (Cf. *Conjunctiva, Diseases of.*) In describing the affections of the eyelids we have to consider the anterior or upper surface, and the structure between the two surfaces.

The upper surface of the eyelid is covered with integument which is continuous with the integument of the forehead and face. It differs from the integument of the forehead and face in being thinner. Under the skin of the eyelids we find the subcutaneous areolar tissue, which frequently becomes infiltrated with effusions, and distended with air in injuries to the nose and air sinuses. The next tissue is the orbicularis muscle, the function of which is to close the eyelids. This is the muscle which is affected in paralysis of the facial nerve, producing inability to close the eyelids, or, as it is sometimes called, lagophthalmus. Beneath this muscle are the tarsal cartilages, upper and lower, the functions of which are to add to the protection of the eye, to preserve the contour of the lids, and, in the upper lid, to give attachment

to the muscle which raises the lid the levator palpebræ superioris.

The tarsal cartilages contain in their substance the Meibomian glands, whose sebaceous secretion lubricates the edges of the lids. The tarsal cartilages are thicker at the free margins of the lids, and gradually taper back to a thinner edge; they are about one inch in length. The upper cartilage is about one-third of an inch in breadth at its center, and narrowing toward its outer and inner extremities has a somewhat semilunar shape. The cartilage of the lower lid is much smaller in width, having a more or less elliptical shape. The free margins of the upper and lower lids —*i.e.* the edges where the anterior or cutaneous surface and the posterior or conjunctival surface meet—lie in contact with each other when the eye is closed, and contain the cilia, or eyelashes, together with the openings of the ducts of the Meibomian glands. The extremities of the margins of the upper and lower eyelids are joined together, and are called the outer canthus and the inner canthus.

These canthi, with the extremities of the cartilages, are attached to the frontal processes of the superior maxillas at the inner sides, and to the malar bones on the outer sides, by the canthal ligament. It is important to bear this in mind in operations on the outer canthi especially.

The inner canthi are shaped somewhat like horseshoes, and at the free extremities of the shoes are the openings of the lacrimal canals, the puncta lacrimalia. Under the tarsal cartilages is the palpebral portion of the conjunctiva.

The eyelids are subject to diseases affecting the integument generally, as well as to affections peculiar to themselves, because of the structures involved.

The departures from the normal which may affect the cutaneous surfaces of the eyelids, either separately or in common with the skin of the forehead and face, are erysipelas, exanthemata, ecchymoses, herpes, edema, emphysema, venereal sores, eczema, and acne.

Erysipelas and exanthematous diseases seldom, if ever, attack the eyelids except as they affect the cutaneous surface generally. Erysipelas is never confined to the integument of the eyelids alone, except that the attack may originate in this situation and spread to other parts. Its restriction to the eyelids, under these circumstances, would be only temporary, lasting, at most, not more than forty-eight hours. The writer has seen a patient attacked with what appeared at the onset to be a purulent conjunctivitis, with eyelids red, swollen, and edematous, together with a moderately profuse purulent discharge from the conjunctiva, develop in less than thirty-six hours into a case of facial erysipelas, the eye symptoms subsiding as the disease spread over the face. There are none of the exanthemata in which the eruption manifests itself first about the eyelids, and when the eyelids are involved it is only as a part of the general cutaneous involvement. Eczema may manifest itself on the eyelids as the result of a general facial condition, or may be secondary to the inflammatory condition of the edges of the lids known as blepharitis; of this we will speak later.

Acne may also affect the eyelids as the result of a general cutaneous affection.

The treatment of these general inflammatory affections of the integument of the eyelids does not differ from the treatment of the same disease when located elsewhere in or on the cutaneous surface. It may be necessary to be cautious in the employment of lotions, embrocations, and ointments, containing irritating substances, because of the danger of injuring the delicate structure of the eye itself, but other than this the treatment of affections of the lids, such as we have mentioned, will not differ from the usual treatment employed when these affections are situated in other parts of the body.

Venereal sores which may affect the integument of the eyelids are chancres, chancroids, and syphilitic ulcers. One would be justified in suspecting the nature of an ulcer or sore on the eyelid in a patient known to be suffering from syphilis. Both chancres and chancroids or sores known to be of venereal origin located elsewhere. Even when specific diseases do not exist elsewhere, venereal sores may exist on the eyelids. When patients present themselves with ulcerations of the integument of the eyelids which do not yield promptly to treatment and which the microscope does not demonstrate to be malignant, our suspicions should be aroused at once as to their possible venereal origin.

Chancres of the integument of the eyelids are not so common as chancres of the conjunctiva, but I do not wish to be understood as intimating that they are commonly met with in the latter situation. They are, however, occasionally encountered in the integument of the eyelids, and are not always easily distinguished, macroscopically, from malignant diseases, especially epitheliomata. The diagnosis may have to be made with the microscope.

The treatment of venereal sores and ulcers will depend on whether their origin is syphilitic; but whether syphilitic or not, their treatment will differ radically from the treatment of malignant growths or neoplasms.

Syphilitic and venereal sores and ulcers of the eyelids will require the local and constitutional treatment commonly given this class of affections without regard to their situation. Malignant growths, on the other hand, will generally require operative treatment.

Herpes affecting the eyelids, oftener the upper, is not uncommon. We commonly meet with a mild form of herpes—fever sores as they are called—but we also meet with a severe form, the two differing so as almost to warrant describing them as different affections. We have herpes in the mild form, occurring as the result of febrile disturbances in children, occasionally also in adults. It may follow exposure to high winds, sunburn, and irritations of the skin generally. The herpetic eruptions from these causes affect all parts of the integument of the face indiscriminately, often both sides at the same time, including the eyelids. There appears a slightly elevated red spot, more or less rounded in outline, varying in size from three to twenty millimeters in diameter, or even larger. This red spot tingles and burns, and in twenty-four hours begins to be vesicular in character, composed of a number of small vesicles. The fluid in these vesicles, which in the beginning is watery, soon becomes flocculent, changing into pus. The vesicles coalesce and break down, forming a scab. If this scab is removed we find the surface beneath ulcerated. Whether removed or not, the sore heals in a week or ten days, leaving a reddened surface, which may persist for a week or two weeks longer. Attacks of herpetic eruption such as this are of frequent occurrence in neurotic people, the result of some slight nervous irritation, or of direct irritation of the terminal endings of the sensory nerves. The course is mild, the treatment palliative, and the prognosis good.

We have another form of herpes, as we have said, known as herpes zoster, which affects the supraorbital branch of the fifth nerve, generally unilateral, and often very serious in its consequences. Herpes zoster is ushered in with violent pain over the distribution of the nerve, producing intense supraorbital neuralgia, which may last a day, or even two days, before the eruption takes place, and at times persisting during and after the eruptive period. The skin of the upper eyelid becomes reddened and swollen, and the lid itself edematous. There is more or less marked febrile action. The eruption appears to be the same as that described in the simpler form of herpes, except that the underlying ulcers are deeper and frequently leave scars. The condition takes its

name from the parts affected, as herpes zoster frontalis, herpes zoster palpebralis, and herpes zoster ophthalmicus. When it affects the eye itself (herpes zoster ophthalmicus) very serious results, even destruction of the eyeball, may follow.

The writer has seen several cases of herpes zoster affecting the eyelids and forehead which have been diagnosed by attending physicians, who were not familiar with the disease, as erysipelas, all coming from malarial districts.

The treatment consists of catbartics, hot applications to the affected parts to relieve the pain, and even opiates may be necessary. During the beginning of the eruptive stage, the intense irritation may be allayed by applications of weak solutions of acetate of lead, lead and opium wash, or carbolic acid. After the vesicular stage has passed, an ointment of carbolic acid and vaseline will soften the scabs and prevent, possibly, the formation of deep scars. In the writer's experience the best results have followed the internal administration of quinine.

Edema of the eyelids is a symptom of importance in affections of the eye itself, as denoting the intensity of the exciting cause, which is generally of an inflammatory nature. Edema may occur in the eyelids also because of disease of organs remote from the eye, as in cardiac and renal disease, and in anemia.

When due to local causes situated in the eye or adjacent structures, the amount of the edema will generally be in proportion to the intensity of the disease which produces it, as well as to the location of the affection. For example, we frequently find in iritis, both primary and when due to cataract extractions, an edema of the lids at the inner canthus. The same will be true of keratitis, scleritis, tenonitis, and inflammations of the eye and its appendages generally. Edema of the eyelids from affections of the eye itself is never so extensive or marked as we sometimes find it as the result of purulent inflammations of the conjunctiva, dacryocystitis, panophthalmitis, frontal-sinus disease, and retrobulbar abscesses or tumors, in which affections it may become so marked as to threaten the destruction of the eye from pressure. Edema of the eyelids may also be present as the result of stings of insects. There is ordinarily very little to be done for edema of the eyelids. When due to renal disease it is more pronounced after rest in a recumbent position; when due to cardiac disease it is more or less constant, although more pronounced after physical exertion. There is no local treatment which will remove edema when due to these two causes. If we find associated with the edema—as we sometimes do—an irritation of the eye and the under surface of the eyelids, we can obtain a certain amount of relief from the use of biborate of soda and tannic acid, each ten grains to the ounce, or a solution of boric acid in camphor water.

When due to inflammatory conditions of the eye and surrounding parts there is nothing to be done for the edema itself—beyond the application of a light bandage—except when the swelling of the lids is so great as to threaten the eye, when the pressure can be relieved by the operation known as external canthotomy, or division of the external canthus. Such extreme treatment is, of course, seldom necessary.

In this connection we may mention an affection of the eyelids which may be mistaken for edema. This is emphysema, due to injury of the nose or of the sinuses which surround the eye. The onset is sudden, following a traumatism, and characterized by swelling of the eyelids, one or both, depending on the situation and extent of the injury. There may be redness of the integument of the lids—which, in fact, is true in any swelling of the lids, even when not of an inflammatory nature; and palpation gives to the fingers a crackling sensation. This distention is apt to be more marked in the lids than in the surrounding parts, for the reason that the integument of the lids is so loosely connected with the underlying parts, and its areolar tissue has so little adipose tissue in its meshes that it becomes easily inflated when the walls of the sinuses, or other air cells which abound in this situation, are broken. No treatment is necessary for the emphysema itself, except in extreme cases, when a bandage may be applied. When the cause of the emphysema is removed the air disappears.

The pathological conditions grouped and described under the heading of skin diseases may affect the integument of the eyelids, acne and comedo being perhaps the least common, while milium, molluscum, and xanthelasma occur frequently; acne merits, at our hands, no description, differing in no way from the acne seen in other parts of the body. Comedones, or black-heads, can be removed, here as elsewhere, excepting that while in other parts they may be removed with the time-honored watch key, or the expressly designed comedo pressers, in the eyelids they are best removed by pressure between the thumb nails. The minute white elevations with sebaceous concretions known as milia, or the larger masses with depressed centers known as mollusca, require a slight incision made in their apices before they can be expressed without the infliction of considerable traumatism, or bruising of the skin.

Xanthelasma, the buff or yellowish-colored patches which are found at the inner part of the lids, and which affect middle-aged people, especially women, can be removed only with the knife or scissors. If they are not too large, the writer's method is to grasp them with a broad-pointed forceps and snip them off with scissors. The skin, which is very loose on the eyelids, can be slightly undermined with the same scissors, and one or two sutures will obliterate all trace of the affection, which is never anything more serious than a blemish. If the xanthelasma is large it may be impossible to excise it without sacrificing more skin than it is wise to remove. In such a case it would be better to advise the patient to tolerate the blemish, with the assurance that it will never assume a serious or malignant character.

We meet occasionally, in or under the skin of the eyelids, with horny and warty growths, lipomata, and cysts. These are easily removed, under either cocaine or general anesthesia, leaving only small scars, which time effaces.

The skin of the eyelids is not infrequently the seat of malignant growths, the most common form being epitheliomata.

Epitheliomata seldom appear in the eyelids before middle age; indeed, most of the cases seen by the writer have occurred long after middle age. The history is alike for all cases; there has appeared a small, roundish, elevated patch or pimple, which may exist for months or even years, without causing very much annoyance. Then without apparent cause, or sometimes as the result of the patient's picking it, this patch or pimple becomes ulcerated, and refuses to heal under ordinary treatment. When these patients present themselves to the specialist the growths have passed, as a rule, into the ulcerative stage, and the patients are prepared to hear that they have malignant disease or cancer.

Even when ulceration has begun, a long time may elapse before the affection takes on a rapidly growing malignant character. There is always, in cancerous affections of the eyelids, a long period during which removal can be effected without serious deformity to the lid, and during which time removal means permanent cure. It is only after the disease has existed long enough to involve the entire structure of the eyelid, the skin, the conjunctiva, and the tissues between, when not only is there a deeply ulcerated spot, but the surrounding tissues are infiltrated, that the question of extensive operation, possibly the removal of an entire upper or lower lid, has to be considered.

It is not just to our patient to conclude hastily that

a suspicious-looking ulcer of the eyelid is a malignant growth, any more than it is to defer action in the hope that it may not be malignant. We of course consider the history of the case, the age of the patient, and other points which may occur to us at the time, but the knowledge which should influence us, and which we should obtain as soon after seeing the patient as possible, is that furnished by the microscope. When we have this information, and are satisfied that a patient has malignant disease, the indications for treatment are very clear. There is but one thing to do in cancerous disease of the eyelid as elsewhere, and that is to remove the offending neoplasm; and, should we elect to remove it with the knife, we should not hesitate to remove sufficient tissue to include not only the growth itself but all infiltrated structures as well.

In removing cancerous disease of the eyelids, ophthalmic surgeons, almost without exception, prefer to resort to the knife. Some of the authorities mention the use of caustics, but the writer has been unable to find, among the various text-books on diseases of the eye, even one which recommends any other method than the knife.

It is safe, as a rule, to be guided by the advice of those who have had large experience and who are considered authorities; the exclusive use of the knife in removing cancerous growths of the eyelids is, no doubt, advocated as the result of experience. One author on diseases of the eye (Noyes) mentions the use of caustics, and his objection to their use is that they leave scars which have to be removed by operation later, while with the knife in the beginning both the cancerous growth can be removed, and the resulting deformity remedied at the same time, which is of course true. Still, a deformity of the eyelid, while it may be disfiguring, is not fatal to life, and many persons have so great a fear of the knife that, to them, death may be preferable. Then too the element of time may be a consideration. A surgeon would hesitate to perform a plastic operation for the removal of a cancerous growth and the repair of the eyelid except under general anesthesia, and with the knowledge that his patient would remain quiet for at least two weeks following the operation, in order to secure proper healing. With the caustic treatment it would perhaps be possible for a patient to attend to his ordinary business occupation while undergoing treatment. We have in mind a case of this kind. An elderly gentleman, earning a precarious living as an insurance agent, with a large and helpless family depending on him, presented himself for treatment for an epithelioma of the upper eyelid. The disease had entered upon the ulcerative stage, and involved a spot in the center of the lid, about three millimeters in diameter. He was willing to submit to an operation providing it did not interfere with his work; he was unable to stop his work for even one week. In such a case it seems as if one would be justified in employing a caustic application. The resulting scar could be remedied at any time, while the epithelioma, if allowed to go on unchecked, would destroy tissue, and involve structures which could be remedied only by great sacrifice, if at all. Dr. A. R. Robinson, in "Observations in the Treatment of Cancer," concludes "that the majority of cases of cutaneous cancer can be removed with the greatest certainty and with least deformity by caustics, provided the patients are seen before the lymphatic glands are invaded." This, of course, applies to cutaneous surfaces generally, but with less force, perhaps, when the disease is in the integument of the eyelid, because of the danger to the eye itself from the caustic application. It is impossible to lay down rules which shall be invariable guides, or to give advice which is to apply to all cases alike, but the writer believes that [illegible] knife is the best method of treatment [illegible] of cancer of the eyelid. [illegible] may be employed with advantage.

Of the affections which are attended with [illegible] of the eyelids, one which is not uncommon is [illegible] ases, or pediculi ciliares. The affection [illegible] by any means confined to uncleanly persons, [illegible] by the specialist or the family physician, and its discovery horrifies the patient and [illegible]. The symptoms are itching and redness of the margins of the eyelids, and, if the [illegible] is neglected, falling of the eyelashes. Inspection reveals the presence of the pediculi on the edges of the lids and the ova pediculi on the lashes. The treatment will consist in the removal of the offending parasites, crushing them between the thumb nails, and the application of some parasiticide. Because of the irritating effect of this drug on the cornea. As a rule removing the parasite with the nails, as mentioned above, and the application of the yellow oxide of mercury ointment, will effect a cure in a few days.

Hordeolum is an inflammation of one of the glands of the skin of the eyelids, situated at or near the margins of the lids, and often attended with considerable swelling and tenderness, and even constitutional disturbance. There are generally a succession of the hordeola, a new one appearing as another gets well, until a dozen or more have appeared. Such a condition has often underlying it some general constitutional debility, and will require for its treatment nourishing diet, fresh air, and tonics. It is doubtful, however, if this condition of furunculosis, if it may be given this name, ever attacks and is confined to the eyelids, even when there is marked constitutional debility, unless there is added to the general derangement a local exciting cause as conjunctivitis, or some weakness or abuse of the eye itself. It is advisable, as a preliminary to the general treatment, to give attention to the local cause. If there is found to be an uncorrected refractive error it should be corrected, and a coexisting conjunctivitis should be treated. For the hordeolum itself, nothing relieves the pain and hastens the termination of the inflammation so much as the application of hot water. Warm poultices, to hasten suppuration when [illegible] be advisable elsewhere, should not be used for inflammations here, because of their effect on the conjunctiva. Some of the most aggravated cases of conjunctivitis the writer has ever seen have been

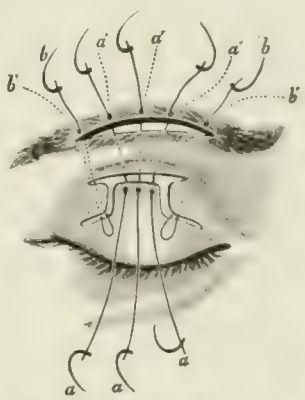


Fig. 2337.—Panas' Operation for Ptosis. (After de Schweinitz.) *a, a.* Sutures uniting flap to integument of brow; *b, b,* sutures advised by Panas to prevent possibility of ectropion resulting.

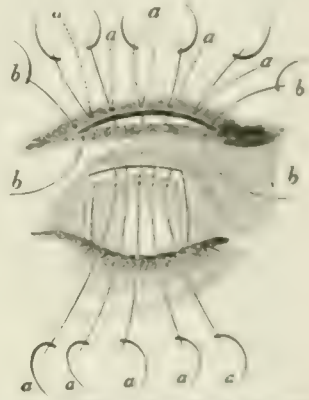


Fig. 2338.—Van Fleet's [illegible] Panas' [illegible] Ptosis [illegible] brow.

caused by the application of flaxseed and tea-leaves poultices. Suppuration is the final outcome of a hordeolum, but it has seldom been necessary in the writer's experience to employ the knife for the evacuation of the pus, this being, as a rule, rapidly brought about by the hot applications. Spirits of camphor has been recommended to abort the inflammatory process, and while it does not invariably accomplish this, the writer has seen beneficial results follow its use.

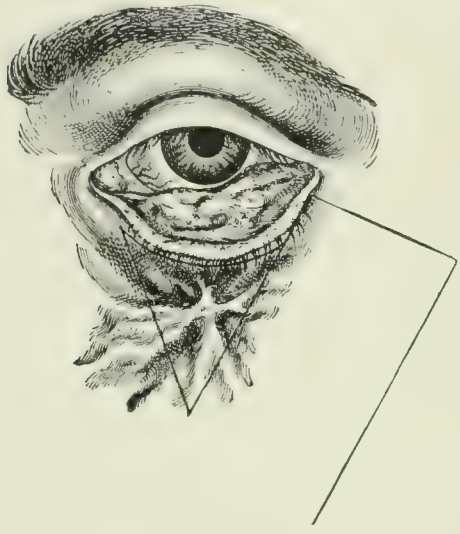


Fig. 2339.

A *chalazion* is a distention of a Meibomian gland with its normal secretion. This is caused by an occlusion of the duct of the gland, which may be either permanent or temporary. The distended gland sometimes becomes inflamed, when it simulates a hordeolum. Ordinarily a chalazion presents itself as a circumscribed swelling, hard to the touch, and of variable size. It may be in either the upper or lower eyelid, and not infrequently there are more than one in the same lid, and they often exist in all four eyelids at the same time. They also are caused by conjunctivitis, which may or may not be due to uncorrected errors of refraction.

A chalazion may sometimes be cured by massage of the eyelids, the accumulation within the gland being pressed out through the duct. When this cannot be accomplished the cyst can be incised and the sac curetted. It has been recommended that the incision be made into the sac through the margin of the lid, or, if the incision is made through the conjunctiva, that it be perpendicular to the margin of the lid, so as to avoid cutting other Meibomian glands than the one involved. While the incisions can be made equally well in either situation, *i.e.* through the margin of the lid or through the conjunctival surface, in some cases, in others the method to be employed will depend on the size of the tumor and its location. There is no danger of the incision destroying other glands in either case, and no evil results ever follow incisions made in either situation.

Blepharitis marginalis can be properly classed as an affection due to the same causes as hordeolum and chalazia. It is possible to have blepharitis as the result of phthiriasis, but the affection commonly known as blepharitis is due either to conjunctivitis or to uncorrected errors of refraction, and more often to the latter.

Blepharitis is characterized by a redness of the margins of the eyelids, with which is associated a scaly condition, and finally by an interference with the nutrition and growth of the eyelashes.

This may be the cause of trichiasis and districhiasis, but oftener it results in the death of the eyelashes, the lids finally becoming entirely devoid of these hairs.

The treatment of this condition is local, and consists in applications to the eyelids themselves, and the correction of errors of refraction with suitable glasses. It is not unusual to see stubborn cases of blepharitis, which resist treatment, or after frequent relapses, finally become cured and remain so, when properly fitted glasses have been adjusted and worn.

Pagenstecher's ointment (Unguentum hydrargyri oxidi flavi) is the local remedy generally employed in this affection. It is often made too strong, when it is very irritating; the greatest care should also be exercised in selecting a proper base, and having it thoroughly mixed. The ointment should never be made stronger than one grain to the dram (except as a parasiticide) and the best base to employ is vaseline. Fatty bases, as cold cream, simple cerate, and others —which contain lard—decompose; the fatty acids alter the chemical nature of the yellow oxide, making,as before mentioned, an irritating ointment. This isan important consideration which should not be forgotten.

Trichiasis and *districhiasis*, together with entropion, are the results of inflammatory affections of the conjunctiva, such as chronic conjunctivitis and chronic trachoma. As a result of cicatrization of the conjunctiva, the tarsal cartilage becomes curved, and the eyelashes, instead of curving outward, curve inward and sweep over the eyeball. The eyelashes can be pulled out, and for this purpose specially devised forceps have been made, called epilation forceps. The relief afforded by this treatment is only temporary and incomplete. The eyelashes grow again, and even if pulled again the inner edge of the margin of the lid rubbing over the eye keeps up the irritation. The radical cure of this condition is by operation, and the writer prefers the operation in which a wedge-shaped piece of the tarsal cartilage is removed. The results obtained from this operation are good and lasting. It is performed as follows: The patient is

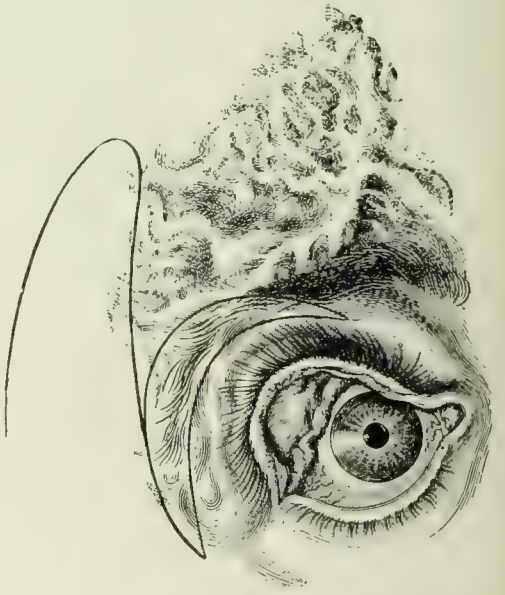


Fig. 2340.

anesthetized (which, by the way, is best in all plastic operations about the eyelids). Cocaine gives satisfactory results only in operations on the eye itself. An incision is made through the skin, parallel with and about two millimeters from the tarsal margin, extending down to the tarsal cartilage. Pushing the muscle and connective tissue aside, the operator should

expose the whole surface of the cartilage and should carry the incision straight down, in such a manner as to involve almost the entire thickness of the cartilage. Sometimes the knife will go through the cartilage, but this does no harm. A second incision is then made in the cartilage, about 2.5 millimeters from the first, tapering to and meeting the first incision at the ends. This second incision, instead of going straight down through the cartilage, is made obliquely, and meets the first incision not only at its ends, but at the bottom

Fig. 2341.

Fig. 2342.

as well. The wedge-shaped piece of cartilage thus formed is removed. A central suture is then passed through the lower edge of the incision in the skin, and through the lower edge of the incision in the cartilage. It is then carried through the upper part of the cartilage, passing over the groove made in the cartilage by the removal of the wedge, and finally brought down through the upper edge of the cutaneous incision. Two more sutures like the first are inserted, one on either side of the central suture, and as many more as the operator thinks necessary. When these sutures are tied the margin of the lid and the lashes will be permanently everted. This operation can be employed only in the upper lid. Operations for the relief of entropion of the lower lid are not nearly so satisfactory. The cartilage in the lower lid being so small, the best we can do is to remove an elliptical piece of skin, which will give relief, often lasting a long time.

Ectropion is the result, as a rule, of cicatricial contractions of the skin of the eyelids, and requires for its relief a plastic operation. We will consider these operations under wounds and burns. There are two forms of ectropion of the lower lid, however, one due to chronic conjunctivitis, in which the hypertrophy of the conjunctiva and the underlying connective tissue everts the lid, and the other the result of senile change, which can be relieved by applications of alum or sulphate of copper to the conjunctiva.

Blepharophimosis, a narrowing of the palpebral orifice, which may be congenital or the result of chronic trachoma, can be remedied by the operation known as cantholysis, or canthotomy. A wire speculum is inserted between the eyelids, and the external canthus put on the stretch. With straight and strong scissors the external canthus is then divided, both mucous membrane and integument, back to the margin of the orbit. The mucous membrane is then lifted with forceps and the external cantha ligament divided. The mucous membrane at the bottom of the wound thus made is united to the integument and at the sides as well. A vaseline dressing is applied, and the stitches are removed in three or four days.

Canities is a name given to white eyelashes, of which there may be one or more in a [illegible] lashes are of darker color, even [illegible] may be congenital, or the result of [illegible] with the nutrition of the cilia. Nothing can be done for this except epilation, which may be [illegible] the white lashes are not too numerous.

Interference with the motor [illegible] paralysis or other causes, is of frequent occurrence and demands attention. The [illegible] dangerous to the patient's sight, and which will often baffle the physician, is the inability to close the eyelids in paralysis of the seventh nerve. In this condition the eyelids are open when awake and when asleep, and the eye becomes [illegible] irritated and even ulcerated and destroyed, from the constant exposure to wind, smoke, and irritating substances generally. If the paralysis is transitory, it may only be necessary to protect the eye with a bandage or with a shield; when the paralysis becomes permanent, however, as sometimes happens, it may be necessary to resort to operative procedure, and to close the eyelids by suturing the upper and lower lids together, first denuding the edges.

The opposite condition to paralysis of the seventh nerve is the inability to open the eyelids when the third nerve is paralyzed. This condition is known as ptosis, and when due to paralysis of this nerve is generally acquired, and amenable to treatment by drugs. Paralysis of the third nerve—the motor oculi communis [illegible] to intracranial growths, when it becomes a very serious condition; in the majority of cases, however, this paralysis is due to acquired syphilis, and responds quickly to antisyphilitic treatment. We do occasionally meet patients in whom ptosis due to this cause persists, even after prolonged treatment, and when we have every reason to believe the syphilis has been cured, and then it is necessary to resort to operative treatment if we desire to remedy the defect. We may not consider it advisable to remedy this deformity always, as we shall consider later.

Ptosis may be due to other causes; it may be congenital or it may be the result of chronic conjunctivitis or trachoma.

In congenital ptosis there may be associated with the paralysis, or imperfect development of the levator palpebræ superioris, paralysis or imperfect development of some of the other [illegible] notably the superior rectus. Any or all of the [illegible] cles may be involved, generally one [illegible] by the third nerve. The writer has seen a patient in whom not only were the muscles supplied by the third nerve affected, but the external rectus, which receives its motor power from the sixth nerve, was also involved. When the superior rectus is involved the eye will be rotated downward, and when [illegible]

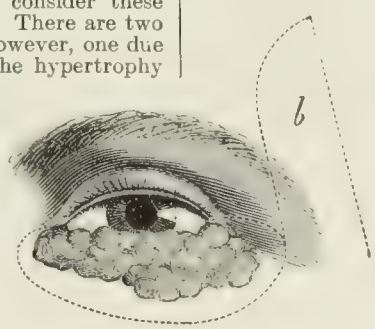


Fig. 2343.

Fig. 2344.

is affected the eye will be drawn outward. The recti muscles are generally affected in syphilitic ptosis, and frequently are not affected in congenital ptosis. They are not involved when the ptosis is due to inflammatory conditions of the conjunctiva. To overcome the ptosis by operation when any of the recti muscles are involved, may, by exposing a deviating eye, produce an annoying diplopia, and this will have to be considered before advising such an operation.

In trachoma, after the disease is cured, a drooping of the upper eyelid will sometimes persist, which may necessitate an operation, and it is in cases due to this cause that our best results are often obtained. Various operations have been devised to overcome this deformity, and the results have been until recently rather unsatisfactory. The levator palpebræ superioris muscle, which raises the upper eyelid, arises in the orbit, from the lesser wing of the sphenoid bone, directly in front of the optic foramen. Its insertion is in the upper eyelid, to the convex margin of the tarsal cartilage. Its action is to draw the lid upward and backward. In the absence or imperfect development of this muscle, and when it is inoperative because of some affection of the nerve supplying it with motor power, operators have endeavored to make the occipito-frontalis muscles—the anterior portion of which is intimately adherent to the skin of the forehead—take the place of the levator. The results obtained by Pagenstecher, De Wecker, and others, have been only partially satisfactory, the effects not being permanent.

Fig. 2345.

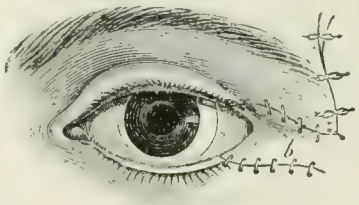


Fig. 2346.

The operation devised by Panas has given satisfactory results, which have been permanent. The operation is, however, somewhat complicated and difficult to perform. The writer has modified this operation, making it extremely simple, and the results in his hands, and in the hands of other operators as well, have been generally successful. It is performed as follows: The patient being anesthetized and the brow shaved, the face and forehead are thoroughly cleansed with a bichloride wash. An assistant then inserts under the upper eyelid a horn shield, and with his free hand steadies the skin of the brow, as directed by Panas. The operator then makes in the upper lid, at or slightly above the upper convex margin of the tarsal cartilage, an incision which commences at the inner side and includes the middle third of the lid. From the inner extremity of this incision another is made extending down to the ciliary border, and a third is made in like manner from the outer extremity of the first. The integument enclosed by these three incisions is dissected from the underlying tissue, down to the ciliary border of the lid, making a flap. A final incision is made in the brow, parallel with the first incision in the lid, but slightly longer. The integument between these two horizontal incisions is then undermined in such a manner as to make a bridge. The parts are carefully cleansed, the flap is passed up under the bridge and secured by stitching its upper margin to the upper margin of the incision in the brow. This is accomplished by means of five interrupted silk sutures. The outer and inner extremities of the final incision (*i.e.* the outer and inner extremities of the incision in the brow after the flap has been stitched in place) are sutured, and the whole is covered with sterilized vaseline and bichloride gauze, and bandaged. The bandage is not to be removed for two days, after which it should be removed daily for a week, when the stitches can be taken out and the dressing discontinued. The epithelium of the flap becomes macerated and exfoliates, and the true skin unites with the under surface of the bridge, of which it becomes a part, or perhaps disappears.

It is not well to make the flap too narrow; it may even be made to include more than the middle third of the lid. Its length should vary with the degree of ptosis to be overcome. Sometimes after the operation the eyelid may not close in sleep, but this is only temporary. Another point to be considered is the tendency of the bridge to curl, causing a scar in the brow. This can be avoided by including the upper edge of the bridge in the sutures which unite the flap to the skin of the brow. The epithelial surface of the flap may also be scarified slightly, to hasten its union with the under surface of the bridge.

This modification differs from the original operation of Panas in that the lines of incision are straight, and extend only through the integument, whereas Panas recommends that they extend down to the periosteum, which must necessitate a longer time in healing, and adds to the operation the danger of wounding deeper tissues, as, for example, the supraorbital nerve.

The object of this operation is to make the occipito-frontalis muscle take the place, or do the work, of the levator of the lid; the flap, uniting by first intention with the upper edge of the incision in the brow, becomes a part of the skin controlled by the contractions of the occipito-frontalis, quite as much as it would if the incisions were deeper. The two lateral sutures advised by Panas to prevent ectropion are not necessary in the modified operation (see Figs. 2337 and 2338).

Blepharospasm is a spasmodic contraction of the orbicularis muscle, present in inflammatory conditions of the eye or the conjunctiva. Occasionally, when it persists and interferes with the treatment of the underlying inflammatory condition, it may be necessary to perform the operation known as canthotomy, which we have already mentioned. Blepharospasm may also be associated with the affection known as tic douloureux. If the cause of the tic can be ascertained, the treatment will suggest itself. In some cases nothing seems to afford relief, and we are compelled to resort to operative procedure, namely, stretching or dividing the trigeminus, or even extirpation of the Gasserian ganglion. Even these extreme measures often fail to give relief. The writer now has a patient under observation who has facial tic with blepharospasm, and who has become an opium victim, whose ganglion was removed many years ago. When last seen this patient was taking sixteen grains of morphine sulphate daily to relieve the pain.

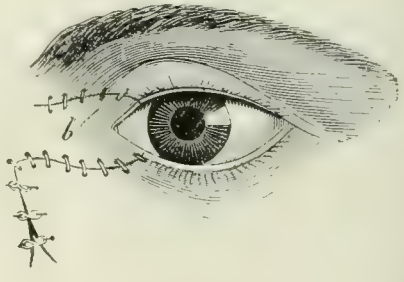


Fig. 2347.

Nictitation, or winking of the eyelids, is due often to local troubles, as conjunctivitis and trachoma. Even uncorrected errors of refraction may be the cause. When due to these conditions, the removal of the cause will effect the cure. At times a general nervous derangement seems to be the cause, when tonics are indicated. One must not expect, however, to cure all these cases, especially when the patients are markedly neurasthenic.

Ecchymosis of the eyelids occurs as the result of traumatism or of paroxysms of coughing, as in whooping-cough in children and in chronic bronchitis in older persons, or it may occur without apparent cause.

When ecchymosis of the eyelids occurs in elderly people without apparent cause, we should be suspicious of atheroma of the blood-vessels, and the interior of the eye should be examined for hemorrhages. We should also bear in mind that a hemorrhage of this character may be the precursor of cerebral hemorrhage. Extremely hot applications are recommended by some authorities as giving the best results in ecchymoses due to traumatism, while others recommend iced applications. The writer prefers the ice for the reason that it is easier to apply, and is therefore likely to be more efficiently applied than hot applications. Either very hot or very cold applications, if resorted to as soon as the traumatism is received, will prevent extensive discoloration of the skin, but neither will accomplish much if the application is delayed. Warm fomentations are not to be advised.

Aside from painting the integument of the eyelid to hide the discoloration, time is the best remedy.

Almost every conceivable injury which can happen to the integument of the body elsewhere can occur about the eyelids. The writer has seen a patient whose eyelid was nearly torn off in a street fracas, and has also seen an eyelid split by the branch of a tree, and by being caught on a butcher hook. Any of these injuries can be repaired while still fresh by carefully cleansing the parts and bringing them together, retaining their apposition with sutures. Larger and older wounds may require extensive plastic operations, the extent and nature of which will depend on the wound.

Burns of the eyelids are not uncommon, and especially gunpowder burns. It is well in powder burns to remove, as thoroughly as possible, all particles of powder which may be in the skin. The only way in which this can be accomplished is to pick the particles out, one at a time, with a forceps or spud. It may take hours of patient work to do this, but the result amply repays the time so spent.

In many, perhaps most, powder burns, only the epithelium of the lid will be injured. When this is the case, it is only necessary, after the powder specks have been removed, to apply bichloride vaseline, bandage the parts, and keep them clean.

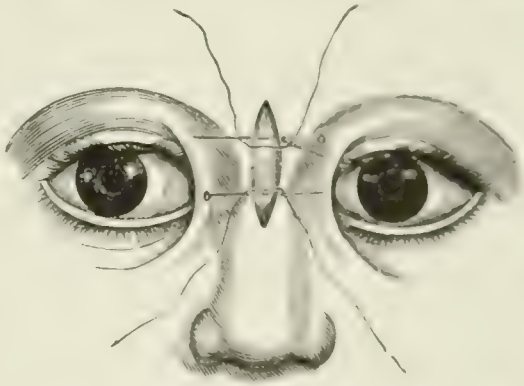
Where more than the epithelium has been injured, it may be necessary to stitch the lids together and resort to skin grafting in order to prevent the deformity which the cicatricial contraction will produce. The method of skin grafting which gives the best results is the Thiersch method.

The repair of damages to injured eyelids, and the relief of deformities occasioned by cicatricial contraction of wounds caused by injuries and burns, will give opportunity for the display of all the ingenuity and skill an operator may possess.

It is impossible to lay down definite rules as to when deformities are to be remedied by skin grafting, and when it may be necessary to resort to extensive plastic operations and the transplantation of large pieces of skin from the forehead and face. As a rule, it is better to reserve the Thiersch method for those cases in which the damage is so extensive that it is impossible to secure enough sound skin from the face or forehead to repair the damage—a condition sometimes found after scalds and burns. There may be times when both the transplantation of [illegible] method may be employed.

An eyelid, or both [illegible] be required to be repaired [illegible] forehead or cheek, or even [illegible] the body, as the arm. [illegible] flap from the arm [illegible] considered only when a cicatricial condition of the face or forehead makes it impossible to secure it from these parts. To remove a large piece [illegible] and transplant it on [illegible] would result, as a rule, in [illegible] so transplanted, unless it remained [illegible] original situation by a pedicle. In order to transplant a flap of skin from the forearm to the eyelid, and still retain the attachment of the flap to the forearm by a pedicle, would necessitate bandaging the arm to the head in a firm, immovable position for at least forty-eight hours. This has been done—indeed, such a transplantation has been [illegible] —the pedicle being severed when the flap has united. Generally, however, it is possible to obtain enough sound skin from the face, except, as we said above, when there is extensive cicatricial contraction. A few general rules are necessary in order to secure a good result in plastic operations. When the margins of the lids are widely separated or everted, by cicatricial contraction, the first step must be to divide the cicatrices and bring the lids together, holding them in proper position with sutures. Every contraction which draws in any way on the margins of the lids should be freely loosened. We shall then have exposed the whole denuded surface which it is necessary to repair.

The next step must be to secure the flap with which to cover this denuded surface. Undoubtedly we have selected the spot from which this is to come before we began our operation, and have been influenced in our choice by the necessity of obtaining a strip of skin large enough to fill in the denuded surface, from a place where it is possible to secure also a healthy pedicle. The flap should be as nearly as possible



[illegible]

devoid of cicatricial tissue, and it is even more important to have the pedicle of [illegible] We have seen transplanted flaps [illegible] cluded superficial cicatrices, but when it is possible to utilize only healthy skin it is better to do so.

The flap should be large [illegible] tension on it or the parts to [illegible] and it should be as free [illegible] tissue. The pedicle by which it retains its continuity with the surrounding [illegible] is possible to make it, and should lie as flat as possible. A slight twist in the pedicle [illegible] result, but any twist which is likely to interfere with the circulation of blood [illegible] In attaching the flap to the [illegible] sired to secure union, fine iron-dyed black silk is to

be preferred. The sutures should be close together, should not be very deep, and should not be tied too tightly. The writer does not recommend the use of harelip pins, believing that when they are necessary there is apt to be too great a tension on the flap to permit of union by first intention. A fatal mistake in plastic operations is to unite the parts before all bleeding has ceased. Severed arteries which persist in bleeding despite torsion should be tied with catgut ligatures, and the oozing of capillaries can be arrested by the application of hot water, or by gentle pressure; we must not use so much hot water that we destroy tissues and cause sloughs. The writer believes in the frequent washing of the parts with a weak bichloride solution during the operation.

After the parts are stitched in place, the spot from which the flap was taken must be repaired. This can be easily accomplished anywhere about the face, because of the looseness with which the integument is applied, by freely undermining the edges and bringing them together. Here is a consideration which must be taken into account when choosing a site from which to take a flap. We must be sure that the bringing of the parts together after the flap has been emoved will not create a tension on the edges to which the flap is stitched after it is in its new position.

Flaps should not be taken from the cheek of a man whose beard is heavy and placed on the eyelid. The writer has seen this done, the flap producing a thick growth of hair which was annoying as well as disfiguring.

When the flap has been stitched in place, and the parts have all been adjusted to our satisfaction, a dressing of bichloride gauze should be placed over the wounds and a bandage loosely applied. This can be removed in two or three days, the parts cleansed if necessary, and the dressings reapplied. It is desirable to disturb the wounds after plastic operations as little as possible. The stitches can be removed, a few at a time, in from three days to a week. (Figs. 2339 to 2347.)

Epicanthus is a congenital defect characterized by a flatness of the bridge of the nose, and by the presence of crescentic folds of skin over the inner canthi. The defect is remedied by removing an elliptical piece of skin from the bridge of the nose and bringing the parts together. (Fig. 2348.)

Coloboma of the eyelid may also be congenital, and is remedied by paring the edges of the coloboma and sewing them together.

Nevus, another congenital defect, assumes a variety of forms. A simple reddened spot, which varies in the intensity of its hue, often is seen in the eyelids of the new-born infant. Frequently these spots disappear in the first few months of life. Sometimes an intensely livid spot may cover the whole lid, or even the whole side of the face as well; when marked, these spots do not disappear, and very little can be done for them. Sometimes the distorted and enlarged blood-vessels may form distinct and irregular tumors. Treatment will be excision by means of the knife, or destruction of the blood-vessels by means of hot needles plunged into them. At times it may be possible to destroy a telangiectatic tumor by tying of the blood-vessels. The variety of these tumors renders it impossible to go into their treatment in detail in this article. Sometimes the results obtained are very satisfactory, and at other times, unfortunately, they are not satisfactory. FRANK VAN FLEET.

Eyes, Artificial.—See *Artificial Eyes*.

Eye-stones.—The opercula of certain species of gastropod mollusks. These organs are horny or calcareous valves, situated in the so-called foot of the mollusks, and serving to close the apertures of their shells when the animals withdraw themselves into them. They are of different shapes and variously developed in different species—in many species they are absent altogether. Those which are used as eye-stones are hard, stony, plano-convex bodies, about as large as split peas, 0.005 to 0.01 meter in diameter (one-sixth to one-third inch), rather longer than broad, with a smooth but rather dull plane, and a very smooth and shining, convex surface. The former has an eccentric white nucleus, from which a brown, right-handed, spiral line reaches the edge in about two turns; the outer portion of this surface is variegated with light-brown markings, and finely striated with numerous lines running in the opposite direction. The convex surface is slightly asymmetrical, the thickest point being nearly opposite the nucleus of the spiral just mentioned. It is brownish flesh-colored in the center, shading to white at the margin. Many specimens are much worn by the action of the sea; these are white as coral, and the spiral structure is difficult to make out. Eye-stones are composed mostly of lime carbonate, and perform entertaining movements occasioned by the discharge of carbonic acid from the surface when placed with the flat side down, in a vessel containing dilute acids. They have long been a popular resource in treating foreign bodies in the eye, for which one is placed under the lid, where it is carried around by the movements of the eye. When it comes in contact with the mote, this is carried along with the "stone" by capillary attraction, and is finally expelled with it. They are a clumsy means of doing what a small amount of skill will accomplish with far more certainty, and are deservedly nearly obsolete. The belief that they are alive and move themselves about in the eye, until they "find" the mote, is a popular fallacy. The demand for them now is very limited, and confined to the ignorant. The supply is also small and uncertain, those of this port (Boston) coming mostly in little lots from sailors who bring them from the Bahamas and elsewhere, as curiosities or private ventures. "Crab's-Eyes," lenticular concretions found in the lining membrane of the stomach of the crawfish, look much like eye-stones, and are described for them by several authors. The description just given will easily distinguish them. W. P. BOLLES.

Eyestrain.—Eyestrain has received so much attention, its effects have been so exhaustively discussed, claims so divergent have been made regarding its effects, that anything approximating a complete review is impossible. Text-books on ophthalmology set forth more or less completely the nature of ocular defects which usually do or do not produce strain. Works on general medicine present it as one of the possible causes of numerous ailments, slight or serious, which beset humanity and add to the trouble of living. It has seemed to the writer that it would be better to present the subject as it has presented itself to him in actual practice rather than attempt an historical review. Indeed, it is almost impossible to credit to any one writer just his share in contributing to what is now general knowledge. What eyestrain is; its symptoms; how, so far as can be thought out, it produces these symptoms; how a case should be studied; why we are sometimes disappointed in treatment; what the treatment should be—these, the writer believes, are matters of greater interest than a review of literature. That this paper contains anything which cannot be found somewhere else is not thought. The purpose is only to present a subject, already somewhat worn, as it is believed thoughtful men now view it.

Strain means overtax; unusual exertion. Given a bit of work, it will be done without strain—(1) if the apparatus doing the work is in normal condition, and the task is not too heavy; (2) if nothing reduces normal functional force; (3) if, in spite of abnormal structure, there is adequate power of adaptation. Eyestrain is

eye work in the absence of one or more of the above. In a little book, published in 1913 on "Eyestrain in Everyday Practice," by Mr. Sydney Stephenson of London, to whom we owe so much for the uplifting of ophthalmic thinking, the opening sentence is: "Eyestrain, a convenient modern expression, may be taken as meaning that the eyes cannot be used, as they should be in a state of health, without entailing a strain upon the muscles, intrinsic or extrinsic, of the eye, which in turn betrays its presence by local or general discomfort." Mr. Stevenson goes on to say that persons subject to eyestrain are usually those in cultivated social circles; that a defect capable of causing eyestrain in one person may be well borne by another; that of all classes it is most common in those whom we relegate to the "neuropathic temperament." These are facts of universal acceptance. Returning now to the conditions under which work can be done without strain, the first is a normal condition of the apparatus doing the work. Applied to the eye, it must be free from defects, congenital or acquired. A small corneal facet, sequel of a forgotten ulcer, one or two points of posterior synechia from a former iritis, may, either by a slight lessening of visual acuity, not appreciated and not observed in a casual examination, or by introducing a local source of irritation, produce indefinite eyestrain. Bad environment, by faulty seating or light in school or at home, may be another source which will defy the best efforts to relieve. Immediate effects of acute illness may be the exciting cause of an eyestrain in either normally or abnormally shaped eyes. Just as the eye is the giving, so can it be the receiving end of remote irritation. Thus, eyestrain can result from anemia, various forms of gastrointestinal disorders, menstrual anomalies, and even at the time of normal menstruation in neurotic girls, eye work may cause severe eyestrain with local or remote disorders. So, too, as regards congenital anomalies. Mention of but one will suffice—antipolar cataract, with reduction of visual acuity. It is not forgotten that in a way all this is a departure from the strict subject of eyestrain. Yet it is important to bear in mind that eyestrain is a matter of differential diagnosis; mere presence of an eye defect capable of producing strain symptoms does not mean that the defect is the cause. This will appear later when adaptation is discussed. Any study of eyestrain must assume that ocular defects, congenital or from disease, have been excluded; that systemic dyscrasiæ have been looked for and not found, or, if found, have been considered in treatment. For instance, the writer has seen children with typical symptoms of eyestrain and with refractive errors fully capable of causing the symptoms; yet, they did not get well. One case, which will serve as an example, was that of a studious girl, who, after uselessly wearing refraction correction three or four years, showed a faint interstitial keratitis. After exhibition of mercury the strain symptoms disappeared and college life was finished without glasses. There seemed no other conclusion than that the hereditary infection had disabled eyes otherwise capable of carrying their own refraction error. But, given careful medical study, there is a large class of cases which do not show any extraocular cause for the symptoms, and diagnosis and treatment of an eye defect remove local or remote symptoms.

Conditions of Normal Eye-work.—How eyestrain is brought about can be best understood by starting with the normal, or emmetropic eye. This eye is so shaped that the fovea is in the focal distance of the refractive media of the eye, when the accommodation is at rest. This means that when the individual is looking at a distance of twenty feet or more away, clear retinal images are formed without accommodative effort. (At exactly twenty feet (six meters) there is a little accommodation, which in normal eyes is practically negligible.) [illegible] adjustment for near [illegible] muscle; in distant [illegible] is reserved for what is [illegible] instance, the emmetropic [illegible] and directed across the [illegible] commodative activity [illegible] lation ceases; blood [illegible] a period of rest. In [illegible] besides ciliary activity. If the [illegible] of emmetropic eyes be changed [illegible] or more feet away to one at [illegible] at five or six feet, not only is accommodation required, but the eyes must be turned in the direction of the object. For instance, if one [illegible] across the street and on a horizontal plane with the eyes, at a book, before him on the table, quite a complicated muscular mechanism is [illegible] and in the language of Dr. George W. Savage, as the "guiding sensation," there is ciliary adjustment in the interest of clear vision. There is also convergence, or the action of the interni. Then the book is below the horizontal plane, and those muscles are called into activity which turn the eyes downward and prevent tilting of corneal meridians. The inferior recti and superior oblique thus get into work. In other words, as soon as the emmetropic eyes are used for anything but distant vision there is a relation between accommodation and other muscular actions which must be preserved if good and comfortable vision is to be maintained. The most important of these is convergence, or the action of the interni. The so-called "meter-angle" of Nagel is the angle formed between the visual lines when the eyes are directed toward an object at one meter distance. To secure formation of a clear image on the retina at this distance the ciliary muscles must exert one diopter of accommodation. In normal eyes this relation must exist all along the line. If the object is at two meters distance, convergence will equal one-half meter angle, if at one-half meter distance, two meter angles, etc. The action of the depressors, elevators, and rotators are similarly regulated, but all depend on the amount of accommodation exerted to secure clear vision at any distance. *The normal eye, which is the standard [illegible] eye-work, is formed on the principles that* (1) *the accommodation muscle shall have rest in distant vision, and* (2) *between accommodation and convergence there shall exist a constant equal relation.*

Conditions Apt to Produce Eyestrain.—In what class of eyes do strain symptoms usually develop? There is practical unanimity of opinion that the hyperopic or short eye is most likely to develop strain, and that if astigmatism be added the probability is greatly increased, while symptoms will be more pronounced. The hyperopic violates both of the conditions pertaining in the emmetropic eye. As Mr. Stevenson phrases it, "the only time when the ciliary muscle of a hyperopic eye can rest is when its owner is asleep." Clear vision without accommodation is impossible because the shortening of focal distance demands increased refractive power, and the ciliary muscle is the only structure which can secure it. When near work is undertaken, the hyperopic person brings not a rested muscle to the task, but one more or less exhausted by prolonged use in distant vision. And here enters a most important and well-recognized fact—eyestrain develops not in eyes with such high error as to be beyond self-correction, but in eyes with low errors which accommodative effort can overcome. This is done by persistent and excessive innervation, with unremitting functional activity. This, again, means unremitting hyperemia. There follow the symptoms of tire, but as these are not always nor indeed generally manifested in the eyes themselves—at least not until brought out by enquiry, if then—and as sight is normal, the real seat of trouble can

easily go unsuspected. When astigmatism complicates hyperopia either as the sole error (simple hyperopic astigmatism) or in addition thereto (compound hyperopic astigmatism), a new element of irritation is introduced. In its simplest possible conception, astigmatism is an error in one meridian of an eye, not existing in the others. As a rule, the meridians of greatest and least errors are at right angles to one another. It is impossible for the owner of such eyes to focus rays accurately in all meridians by symmetrical accommodation, as in simple hyperopia. In spite of this inability, the astigmatic eye will often read test letters correctly. Some claim that this is accomplished by an asymmetrical contraction of the ciliary muscle. Others deny this as a possibility, and attribute good vision in low grades of astigmatism to correct mental interpretation of defective visual impression. In the writer's experience the distant vision of persons with "self-correctable" astigmatism is not absolutely normal in anything like the proportion supposed. Ordinary tests with Green's lines do not show the error, but certain mistakes are made in reading. The round letters—c, g, o, e, q—are confused. So are the uprights—f, l—or the mixed—d, r, p, etc. Still the fact remains that the individual is unconscious of any visual defect. His accommodation secures him practically normal vision. A very common development in these hyperopic eyes, with or without astigmatism, is what is known as "ciliary spasm." The muscle becomes cramped through its unceasing innervation and contraction. This cramp often prevents sufficient relaxation from near adjustment for clear distant vision. Convex glasses blur distant vision, but concave improve. In other words, the eyes though hyperopic—"farsighted," in popular language—are functionally nearsighted. If this diagnostic mistake be made in functional tests, and myopic lenses ordered, the case is made worse; and such blunders are constantly made. The way to escape them will be discussed under Treatment. The hyperopic eye necessarily violates the second condition under which the ideal eye secures good working conditions. Since accommodation must be used in distant vision, though the eyes are parallel, it follows that from distant vision to the nearest close work there must be a modified relation between accommodation and convergence. If the two functions worked equally, as in the normal eye, one would, in distant vision, use accommodation and turn the eyes in. Then his visual lines would not be directed on the object he wanted to see.

Three possible conditions develop from this state: 1. One may be able to separate A from C to exactly the right degree, and so escape eyestrain. This is true of a very large class of young persons. Many of them develop headaches or other symptoms, causable by eyestrain, and yet the existing refraction error has nothing to do with it. Lots of unnecessary glasses are ordered for such children through insufficient diagnosis. 2. One may fall short in the effort properly to separate the two functions. Then one of two things happens—indistinct vision or diplopia. The latter is especially the case when both eyes have normal vision. In effort to rid himself of one or both of these discomforts, the child (the patient is usually in childhood) at this stage abandons the struggle for binocular vision. One eye shows a tendency inward—esophoria—or actually squints inward—esotropia. During the stage of this self-adjustment, various strain symptoms may arise. On examination these children show both the refraction error and the muscular tendency. Later, and specially if one eye has diminished visual acuity, a pronounced inturn develops in the poor eye. 3. The patient may overdo the separation. This means that, finding it necessary to use less C than A, he little by little reduces interni innervation until this itself becomes an added source of eyestrain. In the writer's experience, this is most frequently observed in adults whose refraction error has been inadequately corrected. It is often very difficult to reestablish a working relation within comfortable limits.

Myopia is no doubt less productive of eyestrain than the forms of ametropia discussed above. This is because the ciliary muscle plays so small a part in securing vision. Good distant vision is an impossibility, so the struggle is abandoned. Near vision is obtained without effort. While this is true of simple axial myopia, without organic fundus changes, the writer is convinced that myopia of three diopters or more is a frequent error in the presence of strain. The cause is defective ciliary, producing defective interni innervation. Effort to converge is often too great for comfort. Again, irrespective of degree, if myopia be associated with low grades of astigmatism, strain symptoms are frequent. There is nothing more important in refraction work than to uncover and correct the last vestige of astigmatism. Dr. Risley's epigram, "astigmatism is the turnstile of progressive myopia," should have a secure place in the inner consciousness of every ophthalmologist.

Throughout the foregoing, stress has been laid upon impulse to secure good vision. The part played by the extrinsic eye muscles has been made secondary to accommodative action. Allusion has been made to but one pair of these muscles as a cause of eyestrain—the interni. Even this was shown to be secondary to ciliary action; overseparation of accommodation and convergence. Are these muscles themselves ever a primary cause of eyestrain? Opinions differ widely. As the question has developed in the writer's experience, he believes the truth lies between extremes. Different forms of heterophoria unquestionably do play a big rôle, and there are cases which do not recover till these muscular troubles have received special treatment, be it exercise, prism help, or surgery. Yet, it seems equally true that the more careful and painstaking one is in refraction correction, the fewer cases of this kind come under his observation. The heterophoria either disappears or, if demonstrable by one or more of the various tests, causes no symptoms. It is impossible here to discuss all the varieties of muscular errors. One can indicate only in a general way what experience seems to teach. Assuming that all refraction error has been uncovered and that astigmatism, the champion eye irritant, has been entirely corrected, the meaning of demonstrable heterophoria must be studied. For instance, if with hyperopic refraction, there be a tendency inward—esophoria—is this due to persistant excessive interni innervation, the result of habitual overinnervation of the ciliary muscles (the senior partners of the interni), or is the esophoria really indicative of organic weakness in the externi? The question is not always easily answered. The degree of esophoria, amount of refraction error, behavior of the eyes under ordinary exclusion tests, and the prism-power of the externi—abduction—these, studied together, help to a correct solution. Many years ago the later Dr. Henry D. Noyes of New York, expressed in his text-book the opinion that an abduction below five degrees threw suspicion on the externi. He thought that normal abduction was eight degrees. A large experience has led the writer to believe this is a useful guide. Given an abduction under five degrees he would think it likely that eventually the externi would need help—probably by correcting prisms, bases out. If the prism-power were over five degrees, he would believe that correction of the hyperopic refraction alone would soon relieve symptoms and probably remove the esophoria. With low abduction, and in association with myopic refraction, esophoria is more apt to be an essential trouble because, owing to the myopic shape of the eye, there has been little or no accommodation, and hence no secondary extra

impulse to the interni. On the contrary, innervation of interni may have been below normal. All would depend on the individual's power to separate C from A; *i.e.* use the interni for the proper directing of visual lines, while using no accommodation. It must be borne in mind that the ciliary and interni are supplied by the third nerve, that their nuclei are almost one, and that in normal eyes they work *pari passu*. Yet they possess wonderful power of independent action. If exophoria be studied in its relation to refraction errors, a similar question arises. In myopia is the tendency outward (exophoria) due to defective innervation of the interni, resulting from absence of ciliary innervation or is it due to excessive action of the externi? Dr. Noyes thought that if abduction were ten degrees, twelve degrees, or more, the externi were probably overacting; not so if abduction were normal. Association of exophoria and hyperopic refraction sometimes presents very hard problems. As intimated previously, defective interni action may follow overseparation of C from A in hyperopia. If convex glasses are used for the H, as is necessary, resulting decrease in ciliary innervation may bring corresponding decrease in interni innervation; thus, the muscular trouble is made worse. Fortunately, prism exercise is capable of removing this defect; but it is often a hard, up-hill job. Regarding essential anomalies of the vertical recti (hyperphoria), there can be no doubt that they produce terrific eyestrain. One with normal balance can easily prove this if he will try to read through prisms amounting to even one degree with the base up or down. He will soon know what eyestrain means. In the writer's experience, prism-power of the inferior recti gives a more reliable clue to the importance of an existing hyperphoria than the balance test. These muscles should overcome a prism base up of two and a half to three degrees. When the difference between the lower recti on the two sides amounts to one and a half degrees or more, the inequality will probably have to be reckoned with.

Mention should be made of some other forms of muscular trouble. Dr. Savage has laid stress upon the obliques as a cause of eyestrain. The double prism test in general use often reveals this error, but it would seem that when it is present there are also vertigo and the form of diplopia characteristic of impending oblique paralysis. In other words, we are dealing not with an essential muscular imbalance, but with a central lesion showing itself through an eye muscle. This does not come under eyestrain. With "cyclophoria," outside of its symptomatic significance, and relievable by any form of optical exercise or treatment, the writer has had very little experience. In obstinate cases it is, of course, always looked for, but rarely found. When it is, it is usually associated with oblique astigmatism, and is temporary.

Prism-power of the interni—adduction—with a light at a fixed distance is really nothing more than the power of the interni to separate their own from ciliary action. It has been called positive relative convergence. This power can often be doubled or tripled in a few minutes by exercise with prisms, bases out. Its normal relation to abduction is from 3 or even 5 to 1. It is not infrequently, when defective, a cause of eyestrain, but it does not mean essential weakness nor is its rapid increase to be taken as an increase in muscular power. On the other hand, increase in adduction is often very slowly obtained, and no doubt there is an essential asthenia of these muscles, as with the others. Usually it yields to prolonged exercise. It is often secondary to hyperphoria.

Some writers, notably Dr. Samuel Theobald of Baltimore, have laid stress on the significance of the relation between balance test at infinity and at the reading point. The normal near balance is accepted as two to five degrees of exophoria, as compared with the distance balance. [illegible] exophoria is thought to indicate [illegible] asthenia. There can be [illegible] this contention; but, before [illegible] greatest possible care must be used to [illegible] correct all astigmatism. [illegible] is attributed to increased [illegible] resulting from increase demanded by asthenic ciliary muscles.

What Dr. Savage has called [illegible] is of great importance. The [illegible] sthenic and asthenic muscular [illegible] the former, one muscle is [illegible] in the latter, all are too weak. At the [illegible] one set is farther below normal than its antagonist.

It would seem that this condition exists [illegible] in persons with general muscular asthenia. Sometimes a constitutional cause can be found. Sometimes, systematic prism exercise will increase all the groups; and again, these people demand modification of eye work for an indefinite time.

In conclusion, estimation of the importance of heterophoria involves (1) the diagnosis of its dependence on, or independence of ametropia; (2) the prism-power of each set, that of the externi and inferior recti giving us the best clue; (3) possibility of the muscular anomaly being symptomatic of central lesion, or of some form of ill health; (4) relation between distant and near balance. There is no field in ophthalmic practice where nicer judgment is demanded.

Symptoms or Results of Eyestrain. While symptoms can be measurably divided into distinct classes, they sometimes overlap, and again do not. The latter seems the rule. This is the cause of frequent failure in diagnosis. When psychoses or neuroses are the results, vision normal, and eyes free from local evidence of strain, one will get at the ocular cause only if he has the eyes examined in the course of routine diagnosis. In a general way, symptoms may be divided into vascular, sensory, and reflex. Vascular symptoms usually affect the ocular adnexa—conjunctiva and lids. There is chronic conjunctival hyperemia, with its burning, smarting, etc., but no hypersecretion or other evidence of infection. Hyperemia may show as only a faint circumcorneal flush and be easily overlooked. The lid margins are hyperemic and, in old cases, thickened. Sometimes a fine scaly formation is noticed at the ciliary border. Itching is not an uncommon subjective symptom. Comfort in the open air, and distress in-doors are frequently described. Collyria and salves do not cure such cases: they yield promptly to correction of the underlying error.

A common but not always appreciated vascular result of eyestrain is the reddened papilla, sometimes accompanied by a haziness of the disc border which suggests a low grade of optic neuritis. It has been well described by a number of authors, notably by Dr. Risley of Philadelphia, who regards it as indicating possible serious intraocular disturbance at an early stage. At times one is startled with the ophthalmoscopic picture. The disc [illegible] of the disc, the blurred outlines, and tortuous veins form a combination very suggestive of [illegible]. One is often led, after taking the visual field and making other tests for intracranial disease, [illegible] advice of a neurologist before treating [illegible] of eyestrain. Yet, after removal of the strain proper time to allow irritation to subside, all disappears. This is no doubt the pseudoneuritis described by authors and mentioned in Mr. Stevenson's book. He seems to regard the [illegible] the ground that it does not disappear. Nor does it during the average time of observation; but in the writer's opinion it usually does after an indefinite time. Prolonged cycloplegia appears to be the best remedy.

Sensory symptoms of eyestrain may affect the eyes themselves, cause headache or neuralgia or even remote pains in the back, and neck. The eye pains are usually described in one of two ways: behind the eye or as a feeling of distention in the eye itself. Pains of this kind of course call attention to the eye. It is hard to draw conclusions from the locality of pain; and yet the former is usually relieved by refraction correction, and rarely is heterophoria a contributing cause. On the other hand, the distention pain—"feeling as though the eyes would burst"—and coming after prolonged eye work theater, travelling, etc., is very suggestive of muscular imbalance. Dr. Stevens has laid stress on this in various papers. The time when pain comes has been thought somewhat indicative of its cause. In all forms of eyestrain pains, the usual time is soon after eye work in undertaken. Dr. Noyes (if the writer's memory is correct) first called attention to early morning pains as indicative of muscular imbalance. Patients will often describe pain as striking the eyes as soon as they are opened. One can readily see how, for instance, in a case of low vertical imbalance, unconscious effort to fuse vertically displaced images will be most felt when the eyes, relaxed to the utmost during sleep, first resume the unequal burden. Morning eye pains, especially if they awaken one, are commonly due to nasal or sinus disease. The usual and characteristic form of headache, due to eyestrain, is the band-like pain about the forehead. Less common, but equally suggestive of ocular cause, is vertical pain or even occipital. Indeed, there is no locality about the head which may not show distress signals when the eyes are at fault. The very presence of any headache should call attention to the eyes. Temporal neuralgia is, in the writer's experience, less characteristic of eyestrain than the forms of headache mentioned; but there are many exceptions.

Over migraine and its possible eye origin, the battle has raged fast and furious for a generation. Far-reaching claims have been made by one set of advocates, only to be denied *in toto* by others. Possibly one extreme can be well set forth by a quotation from Mr. Stevenson's book, the date of its publication being 1913, though the paper was first published in 1888. Mr. Stevenson presents the well-known views of Dr. George M. Gould in his Biographic Clinics, and then adds: "It is nowadays very generally admitted that most cases of migraine are closely connected with eyestrain, and that they can be cured by the provision of proper glassess." The special passage is from the pen of Georges Martin, and, according to Mr. Stevenson's reference, appeared in *Annales d' Oculistique*, 1888, tome xcix, pp. 24 and 105, "Dr. Martin insisted upon the connection between astigmatism and migraine, although he did not deny the influence of two other factors, viz., (*a*) a constitutional or diathetic element, the "arthritic," and (*b*) an occasional cause, accordin to the particular case. In proof of the important part played by a partial contraction of the ciliary muscle in the production of migraine, Martin adduced the following points: (1) That partial contraction of the ciliary muscle could be found in the eyes of all migrainous individuals; (2) that when one eye was alone astigmatic, migraine was always localized over that eye; (3) that when the two eyes were astigmatic to an unequal degree, the most frequent and violent crises of migraine appeared over the eye which presented the greater anomaly; (4) that migraine disappeared if spasmodic contraction of the ciliary muscle were overcome by means of atropine; (5) that the constant use of cylindrical glasses correcting the asymmetry of the corneal meridians modified very sensibly the migrainous state, and sometimes yielded complete and lasting cures."

This is one side of the controversy. On the other hand, in Osler's System of Medicine, published in 1910, Smith Ely Jelliffe, writing on Migraine (Vol. VII, p. 752) discusses the vasomotor, toxic, and reflex hypotheses of etiology, and then adds: "The organs which have been declared at fault have been the vasomotor centers, the sympathetic, the gastrointestinal canal, secretory, excretory, ductless glands, organs of generation, male and female, the various organs of sense, the eye, ear, nose, tongue, the muscles of the body, and the general metabolism of the entire body, the brain in general, the cortex, the pons, the thalamus. Many authors pick out several factors; others confine themselves to one. Some faddists say it is eyestrain, others earstrain, others masturbation, while others blame corsets, tight collars, or the wearing of high hats." Again, on page 764, Dr. Jelliffe says; "It is folly to shut ones eyes to the very evident clinical fact that certain migraines are relieved, if not entirely wiped away, by the correction of some peripheral disorder, sometimes more than one, which has had definite action on the nervous system. Just what the differential relation may have been between the severity of the irritant and the mildness of the attack is impossible to judge, but certainly the relief from eyestrain, from diseased turbinates, from adenoids, from constipation, from dysmenorrhea, from a number of minor yet definite peripheral irritations, will relieve a certain number of patients. Perhaps they are the very slight ones, perhaps not; we are not yet in a position to say. One should, therefore, eliminate at the outset such of these structural defects as are shown to have some influence on the nervous system. In denying any possibility to these influences in the causation of migraine one errs almost as badly as when maintaining some one of them to be the only element in the case, as faddists are doing and always have done."

Migraine is allied to a number of remote disturbances, physical and psychical, which are by common consent regarded as "reflex," or vasomotor in character. In the present state of our knowledge they fit there as well as anywhere. Chorea, habit-spasm, indigestion, constipation, grave forms of abdominal distress simulating appendicitis, insomnia, epilepsy, vertigo, etc., have been from time to time attributed to eyestrain. Concerning all this, de Schweinitz says ("Diseases of The Eye"): "That true migraine is caused by astigmatism alone is doubtful; that the correction of astigmatism is an important, indeed, an essential, part of the treatment of this affection should not be disputed. Furthermore, all manner of reflex nervous disturbances, vertigo, pseudochorea, habit-spasm, epileptiform convulsions, melancholia, neurasthenia, tachycardia, night-terrors, flatulent and other types of dyspepsia, indigestion, and even constipation are the frequent results of astigmatism, not only when the error is of high degree, but commonly, indeed more commonly, when it exists in low grade, and often unassociated with any symptoms which prominently direct attention to the eyes as the cause of the distress. Pains strangely and persistently situated in the nape of the neck, between and under the shoulder blades, in the precordium, at the end of the spine, and deep in the mastoid may owe their origin to the same cause. Tilting of the head and shoulders is often the result of astigmatism, and that the same refractive anomaly is the exciting cause of some of the cases of lateral curvature of the spine so often seen in young subjects has been shown by G. M. Gould."

These quotations present quite adequately the present stage of professional thought regarding the relation of eyestrain to such profound nerve storms as migraine, epilepsy, etc. Pathogenesis cannot be satisfactorily explained; at least, if it has been the writer does not know it. Yet, there is overwhelming clinical evidence that faulty eye work may enter into all these things, sometimes only as a contributing factor as evidenced by the numerous cases of disappointment in which capable ophthalmologists have

done their best work. The one certain lesson we should gather is that in all these neuroses the eye may be a factor, and that no diagnostic review is complete until the eye condition is looked after. The same is true of numerous other possible sources of reflex irritation.

Finally, just mention of an ocular result which does not get the attention deserved—lacrimation. Direct nerve connection can be traced between the ciliary body and the lacrimal gland, and not a few cases of "epiphora" have their origin in eyestrain.

How eyestrain produces its results seems fairly clear along some lines, while in others it is hypothetical. We must accept clinical facts, backed up, as they are, by countless reliable observations. Starting with the type of eye which usually produces strain symptoms, it is seen that unremitting and excessive muscular action is demanded in the interest of good vision, obtainable in this way and in no other. Sometimes, as in astigmatism, muscular contraction must be asymmetrical. This state of things demands incessant, excessive, and sometimes uneven innervation, while all physiological muscular activity means hyperemia of the muscle itself. Given, then, the constant hyperemia, it is not difficult to trace its effects forward and outward through the iridic, long ciliary, anterior ciliary vessels to the subconjunctival space, and thence to the conjunctiva and lids. Equally easy is it to involve the uveal coat, behind the processes, by direct continuity of blood supply, and thence through the anastomotic branch, where the optic nerve passes through the choroid, with the papilla. Also, when one considers the close coaptation of the ciliary processes to the unyielding sclera, pressure is readily inferred. There is an abundant nerve plexus, largely from the fifth, in the processes to receive this pressure, and to transmit its effects to other branches of the same nerve, or, through the lenticular or deeper ganglia, to the autonomic system. Part of the area, usually painful from eyestrain, is supplied by the fifth. So is the lacrimal gland. In addition to the ocular end of this abnormal physiology, one can theorize on the irritating effects of abnormal nerve force from the cerebral end. Add to this the connection with the autonomic system, and it is possible to trace, almost endlessly, various forms of what we call "nerve irritation;" it seems hardly profitable to do so. In his article in Posey and Spiller's "The Eye and Nervous System," Dr. Howard F. Hansell gives a schematic representation of the source of irritation from the eye to stomach, involving the autonomics and pneumogastric.

There are other factors contributing to production of extraocular symptoms: the unnatural position of the head in certain forms of astigmatism or heterophoria, similar unnatural positions of the body, as in leaning over a desk, getting close to the print in order to obtain a larger retinal image, and such outside influences as faulty light, defective or excessive, faulty seating in school or at home, etc. These are but factors in diagnosis and treatment.

Treatment.—The treatment of eyestrain demands removal of its cause. It is hoped that the foregoing has made it clear that this is not merely discovery and correction of a manifest refraction error or a form of muscular imbalance. There is not a single symptom of eyestrain which cannot come from something else. The writer has tried to emphasize this elsewhere. ("Ocular Neurasthenia," Sec. Ophth. A. M. A., 1907; "Autointoxication," etc. Ibid, 1910). Many cases go unrelieved because of either insufficient general diagnosis or inadequate eye examination. As hitherto stated, ametropia or heterophoria may exist in the presence of strain symptoms and yet not cause them. Numerous cases are recorded in which manifest ocular symptoms have yielded, not to eye treatment, but to treatment of nasal troubles, gastric or intestinal indigestion, operation for chronic appendicitis, etc. Still, [illegible] most frequent [illegible] imperative; but the ophthalmologist [illegible] broad enough view to recognize [illegible] extraocular causes.

How should an eye examination for [illegible] be conducted? First, and next [illegible] under complete cycloplegia. [illegible] to all persons under thirty-five or [illegible] over forty. The claim that so-called "instruments of precision" (ophthalmometer, phorometer, etc.), or even skiascopy, can do [illegible] is, in the writer's opinion at least, the [illegible] sense. The eye is not only an optical machine; it is a human organ, and possesses its [illegible] idiosyncrasies. Relation between existing ametropia and muscular imbalance modifies greatly the [illegible] of mechanical measurements. Correct [illegible] impossible without cycloplegia. Benefit [illegible] plegics comes from (1) the removal of local effects of eyestrain. Paralysis of the ciliary muscle, relief from persistent hyperemia, and cessation of function act as direct curative means. Eyes causing strain symptoms sometimes resist the action of cycloplegics for a long time. Mydriasis is not cycloplegia. One should not accept the accomplishment of [illegible] plete ciliary paralysis until he has confirmed his subjective results at two or three examinations. (2) Cycloplegics are the only means of removing ciliary spasm. (3) Benefit comes from determining static refraction. Until one has this he has no [illegible] basis of reasoning. Of course it is conceded that skilled ophthalmoscopists come constantly pretty closeto the error without cycloplegia; indeed, that often measurements with and without paralysis balance; even so, the therapeutic result of rest is missed.

Enough has been said of proper appreciation of accompanying muscular imbalance. Again, one must recognize that while some cases show benefit at once, others are slow in responding. It takes time for the eyes to unlearn habits. While they are doing so, a patient may have to sacrifice clear distant vision for the sake of ultimate good. In another class of cases, glasses improve vision to normal or over, and yet force into activity a hitherto unused ciliary muscle with resulting pain. This is the case when myopia is corrected. Normal relations are established after a while. In a word, there should be a clear understanding between doctor and patient regarding what the former is doing, and what the latter may expect.

Finally, in all cases of eyestrain one must consider what may be called the personal equation of the patient. There are those who will be refreshed and invigorated by a walk of a mile. That is their natural limit. Pressed beyond that, they go to pieces. The same reasoning applies to eyes. Eyestrain can be kept up by too much work; *i.e.* too much for a particular person. The so-called rapid pace of our American life has affected schools as well as [illegible] industries. It is just as important to determine one's eye work limit as to correct physical causes. Of course, malingering and hysteria have to be excluded; but neither is insurmountable. Nervous children can be thrown into utterly unproductive work by dread of the coming headache after a certain amount of study. Dyer's method of gradual increase—now so old as to be almost forgotten [illegible] essential thing in treatment. If the child is hysterical, he soon learns that he can do more work and little by little does it. If he is malingering, substitution of an interesting story for uninteresting arithmetic tempts him to self-betrayal. If he really has defective working capacity, it is [illegible] process as advances a boy from half-pound Indian clubs to pegpole climbing.

It seems unnecessary to present illustrative cases. The writer is aware that many things of importance have been hardly more than [illegible]

may have escaped him altogether. His object has been to start with the acceptance of eyestrain as an admitted fact, to group recognized causes, to compare them with normal conditions, and to indicate some of the diagnostic and therapeutic pitfalls which beset us. HIRAM WOODS.

Fabiana.—PICHI. The dried leafy twigs of *Fabiana imbricata* R. et P. (fam. *Solanaceæ*).

This large evergreen, heather-like shrub is common upon high dry hills in Chile. It is rather closely related to the tobacco plant. Only the small twigs should be collected, though much of the drug of commerce formerly included the large woody branches, or even the trunks, several inches in diameter. The branchlets are slender and crowded with leaves. The bark is ashy gray and finely roughened by minute, short, sharp, thickly set longitudinal ridges and minute gland-like protuberances, both of which exhibit, under the lens, a peculiar resinous structure. The bark of the trunk and larger branches scales off in ragged strips. The bark is rich in the resinous constituent, which exists also, to a much smaller extent, in the young wood, but is practically wanting from the old wood. The leaves are broadly ovate and thick, about a line long, bluish or whitish-green by reason of the resinous exudation, which is profusely deposited at their bases and edges. Toward the ends of the branches are numerous very short branchlets, each terminating in a persistent white or bluish flower, which is funnel-shaped and from a third to a half-inch long. These flowers are rarely seen in the drug. Five unequal, included stamens are borne upon the constricted portion of the corolla. The style is slender, the stigma small and two-lobed. The fruit is a two-celled capsule, about one-fifth of an inch long, and contains several brown seeds.

The important constituent of pichi is a large and variable amount of a bitter resin. Associated with this is a little volatile oil, the important constituent of which is *fabianol*, and to which the peculiar odor of the drug is due. A fractional amount of the alkaloid *fabianine* and a fluorescent glucoside, occurring in bitter crystals and resembling esculin, also occur, together with gum, an inert crystalline resin, and ordinary plant constituents.

Pichi is a highly valued drug, both with the laity and with the profession, in Chile and other South American countries, and was introduced into use in the United States by the present writer (*Ther. Gaz.*, 1885, p. 810). Its special repute is for the treatment of vesical and renal troubles arising from the uric-acid diathesis and for the expulsion of gravel and small calculi. It also acts as a sedative to the irritable mucous membrane, modifying the secretion and subduing the pain. The following account of its action and uses, by Beaumont Small, in a former edition of this work, can scarcely be improved upon:

"Its use has been extended to all forms of acute and chronic inflammation of the urinary organs, and numerous reports of cases in which it has been employed tell of its beneficial action, not only in cystitis and vesical irritation due to simple causes, but also when these have arisen from gonorrheal and prostatic disease. A special indication for its use is said to be the presence of pus in the urine. Dr. Reginald Harrison, after using the drug for four years in private and hospital practice, stated that he obtained considerable benefit from it, particularly under the following conditions: (1) In renal colic and the passing of calculi through the kidneys and along the ureters attended with hematuria; though not exercising any solvent power, it seems by its action on the tissues in some way to favor the escape of the stone, and thus to suppress the bleeding. (2) In the hemorrhage which frequently accompanies cancer of the bladder. (3) The sedative action of the drug on the mucous membrane of the bladder has proved beneficial in many instances of irritability connected with an enlarged prostate.

"In addition to its employment in urinary disorders, it is recommended for the relief of the headache, dyspepsia, and other symptoms arising from a condition of lithiasis, and has been used as an hepatic stimulant for jaundice and dropsy due to hepatic disease. Given in small doses, preceding the meal, it has been found to be an excellent stomachic.

"The drug is generally administered in the form of a decoction or fluid extract. The decoction is prepared by adding one ounce to twenty ounces of water, the whole to be given in four portions during the day. The dose of the fluid extract varies between ten minims and two drams. The average dose is from half a dram to one dram. The effects of the drug are usually experienced after a few doses have been given. The extract is not miscible with water, and the appearance of the mixture is made more pleasant by rendering it alkaline. Glycerin is recommended as the best vehicle for its administration; it is a fairly good solvent, and maintains the drug in suspension in fine particles. Salines should not be combined with it, as they cause the separation of the resin in dense curds. Fluid extracts of hyoscyamus, hydrangea, buchu, and other remedies may be combined when they are indicated. A solid extract allows of its administration in powder in capsules. The dose is gr. ii.–x. (0.12–0.6)." HENRY H. RUSBY.

Fabricius ab Aquapendente.—Hieronymus Fabricius, or Girolamo Fabrizio, surnamed ab Aquapendente to distinguish him from another surgeon, a contemporary of the same name, was born at Aquapendente in the Papal States in 1537 and received his education in Padua under Fallopius, whom he succeeded in the chair of anatomy and surgery in the university of that city. Although his name is not preserved among the anatomical eponyms he nevertheless contributed greatly to the current knowledge of anatomy. He was also an embryologist, and by his researches on the embryo of the chick did much to advance that science. He is credited with having been the first to describe the uterine decidua. While not the discoverer of the valves of the veins he was the first to describe them fully and to explain their uses; this he did in a treatise entitled "De Venarum Ostiolis," published in 1603. He also added to the knowledge of the structure of the various parts of the digestive tract and described the muscular coat of the bladder. Harvey studied anatomy under Fabrizio and it is possible that the latter's speculations regarding the function of the valves of the veins may have started the train of thought that led to Harvey's great discovery. Fabricius died in May, 1619.

Fabricius was no less a surgeon than an anatomist. He described hydrocele and devised an operation for its relief and also advised paracentesis for the cure of empyema. Among his writings may be noted: "De Formato Fetu," Padua, 1600; "De Visione, Voce et Auditu," Venice, 1600; "Tractatus de Oculo, Visus Organo," Padua, 1601; "De Locutione et ejus Instrumentis," Padua, 1603; "De Respiratione et ejus Instrumentis," Padua, 1605; "De Gula, Ventriculo, Intestinis Tractatus," Padua, 1618. An edition of his complete works ("Opera Omnia Anatomica et Physiologica"), edited by Albinus, was published in 1737. T. L. S.

Fabricius Hildanus.—Gulielmus Fabricius, Wilhelm Fabriz, surnamed Hildanus, from his birthplace, to distinguish him from his Italian contemporary Fabricius ab Aquapendente, was born in Hilden, a village near Cologne, on June 25, 1560. He received his medical education at Cologne and Lausanne and

then made a tour of the universities and clinics in France and Germany, studying surgery especially. Upon completing his studies he began the practice of surgery in Lausanne, but later went to Berne. The latter city in 1614 granted him citizenship and a pension, and he was appointed physician to the embassies of France and Baden. He suffered for many years from gout and finally died of this affection on February 17, 1634.

Fabriz was one of the greatest surgeons of his day in Germany, being called the re-creator of surgery in his

Fig. 2349.—Wilhelm Fabriz.

native land. He is said to have been the first surgeon to amputate the thigh for disease. Like his namesake in Padua, he was both a surgeon and an anatomist and, though more the first than the second, he maintained that no one who was not an anatomist could be a good surgeon. The following are the titles of a few of his published works: "De Gangræna et Sphacelo," Cologne, 1593 and Berne, 1603; "De Ambustionibus," Basel, 1603; "Gruendliches Bericht von den Blasenstein," Basel, 1628; "Kurze Beschreibung der Fuertreflichkeit, Nutz and Nothwendigkeit der Anatomey," Berne, 1624. A complete edition of his works ("Opera Omnia") was published at Frankfort in 1652.

T. L. S.

Facial Hemiatrophy (Hemiatrophia facialis progressiva, aplasie lamineuse progressive) is a rare affection. Properly speaking, the term should be applied only to those cases in which all the tissues of one side of the face, including the bony parts, undergo a progressive atrophic change. The atrophy may begin in only a part of the face or at first appear to affect only a special tissue. According to Oppenheim, the most common point for the onset of the trouble is in the region of the orbit, but he describes and pictures a case in which the atrophy began in the cheek and another in which, in the beginning, only one side of the chin was affected.

The condition is slowly progressive and in its course usually affects all the tissues of one side of the face, leading to a marked asymmetry. The skin may at first show only pigmentary changes or the hair may fall or turn gray. In later stages the skin is thin and feels inelastic and there is yellowish or brownish discoloration. The subcutaneous tissues may be completely atrophied. The muscles may also be atrophied on the affected side but there is no distinct facial palsy. The muscles of the tongue may also be atrophied. The atrophied muscles do not give the reaction of degeneration when tested with the electric current. The most striking atrophy occurs in the bones of the face and the line of demarcation of the affected from the unaffected side may be marked on the forehead by a distinct groove. The implication of the [illegible] described by Schlesinger. Körner reported [illegible] of the auricle and Hollmeyer, in one case observed a depression in the hard palate. In most cases the parts affected are confined to those receiving the distribution of the fifth cranial nerve. [illegible] injury to the fifth nerve or the Gasserian ganglion is not usually noted. Hollmeyer has reported a case with herpes, but objective sensation in the face in all forms is usually normal. Sweat secretion may be increased or diminished. The secretion of tears is usually normal and the corneal and pharyngeal reflexes are normal. The eye on the affected side generally appears to be deeper in the orbit than on the normal side but the ocular movements and reflexes are generally normal. A combination of this condition with oculomotor palsy and disturbance of pupillary reflexes has been reported by Salomon and by Gowers and others. Also cases have been recorded in which facial hemiatrophy was combined with atrophy of the body on the same side or on the opposite side (Lunz, Volhard), but it is doubtful if these cases are genuine cases of facial hemiatrophy in a strict sense of the term. Various functional neuroses are not infrequently found in these cases—neuralgia, hemicrania, psychoneuroses, chorea, and facial spasm; also organic diseases may be present such as tabes, syringomyelia, and multiple sclerosis. Oppenheim speaks of having observed cases in which symptoms of paralysis and irritation of the sympathetic system were present. Jendrassik has made a similar observation. Schlesinger has observed bilateral facial hemiatrophy with symptoms referable to the sympathetic nervous system. In twenty-six out of eighty-three cases collected from the literature by Klingmann, vasomotor symptoms were found.

Fig. 2350.—Right Side [illegible] in the forehead and the absence of [illegible] (After Klingmann.)

The diagnosis of the condition should not be especially difficult. Congenital anomalies causing facial asymmetry will be recognized by the history and the fact that they are not progressive. Facial atrophy which sometimes occurs in syringomyelia is distinguished by its association with sensory changes. Atrophy of facial muscles [illegible] does not affect the skin or bony tissues and the reaction of degeneration is present in the paralyzed muscles. The facio-scapulo-humeral type of muscular dystrophy does not cause atrophy of the [illegible] as seen in progressive facial hemiatrophy.

The condition usually develops between the ages of ten and twenty years. It may develop in early childhood but is very rare over the age of thirty years. The cause of the condition is unknown. Traumatism to the head or face has been present in the history of some cases; even slight operations such as teeth extraction or the removal or adenoids have been considered as causes. A certain number of cases develop after infectious diseases: diphtheria, measles, erysipelas, and whooping-cough. Oppenheim believes that a neuropathic heredity plays some part but it is not present in all cases. Bannester and also Klingmann mention frostbite as a possible cause in cases observed by them.

The PATHOGENESIS of the condition is decidedly uncertain and the few postmortem examinations that have been made (Mendel, Touche, Loebl and Wiesel, and Grabs) throw no light on this point. It is generally classed as a trophoneurosis. The clinical evidence—absence of sensory changes, etc.—is against the idea that the Gasserian ganglion is implicated as is also the fact that after operations on the ganglion or alcohol injection no general atrophy of the face occurs. These operations are practically never done before the age of thirty, however. Bitot suggests the possibility of a primary skin lesion. Moebus advances the hypothesis that the condition is due to some infectious process in the neighborhood, the infection being presumably carried by the lymphatic system. Brissaud would locate the primary lesion in the gray matter of the floor of the fourth ventricle. Oppenheim favors the theory that the sympathetic nervous system is the source of the trouble and quotes Bouveyson, Barrel, and Souques as reporting cases in which the condition was associated with a pleuritis of the apex of the lung, causing irritation of the cervical sympathetic ganglia. The presence of vasomotor symptoms in many cases favors this theory.

The PROGNOSIS is not good for recovery. The progress of the disease is usually arrested at some point after which the condition remains stationary.

TREATMENT is generally without influence. Oppenheim saw some improvement in one case after the removal of a swollen lymph gland which was in the neighborhood of the superior cervical ganglion. Sympathectomy apparently has no effect on the condition. Cosmetic improvement may be obtained by subcutaneous injections of paraffin, but the operation is not always successful and is not without danger.

C. D. CAMP.

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Facial Hemihypertrophy.—A rare condition characterized by an overgrowth of the tissues of one side of the face usually congenital or developing in early childhood. It may be accompanied by a half-sided hypertrophy of the extremities. It appears that the condition was first described by Beck in 1836. In 1898, Sabrazes and Cabannes were able to collect from the literature eighteen congenital cases and five acquired cases. In 1904, Mackay collected twenty-eight cases from the literature and added another observation. He made no special distinction between congenital and acquired cases but many of the cases would be included only if the term was used in the widest sense, for instance, Stilling's cases of telangiectasis and Dana's case of acromegaly in which the enlargement affected the extremities on both sides but only the left half of the face. In congenital cases the sexes are equally affected. The condition may not be noticed at birth. There is no instance on record in which this malformation has been hereditary or where more than one member of the family has been affected. Both the bones and soft tissues are implicated as a rule. The lip, tongue, teeth, and hard palate may all be involved. When the ear is affected the lobule usually shows the greatest enlargement. The skin is often discolored, reddened, and may show increased secretion. Salivary secretion may be increased on the affected side (Friedreich, Ziehl, Sabrazes et Cabannes)

FIG. 2351.—Facial Hemihypertrophy in a Child. (After Sabrazès and Cabannes.)

but the salivary glands are not enlarged. The motility of the face and the electrical reactions in the muscles are usually normal. The special senses and the intelligence are usually not affected. The condition is much the same in the acquired cases as in the congenital except that the teeth and tongue are not affected.

Apparent etiological factors in the acquired cases have been: traumatism, trifacial neuralgia, abscess of the jaw (Montgomery), and acromegaly; in other cases (Schieck et al.) no apparent etiology was found. Minors observed a case of facial hemihypertrophy follow extirpation of the cervical lymph glands. In the congenital cases the condition is probably due to some factor influencing the development of the branchial arches, although other factors may play a part. Since the hypertrophy is usually localized to parts supplied by the trigeminus, a neuro-

trophic origin may be suspected, but the evidence is not sufficient to prove that such a view is correct. The frequent occurrence of vasomotor symptoms in these cases would also suggest the sympathetic nervous system as being primarily at fault. The hypotheses that associate the condition with lesions in the floor of the fourth ventricle or with primary skin lesions (Hutchinson) have nothing to support them.

The diagnosis of the condition is not difficult but it should be distinguished from unilateral acromegaly, from hemicraniosis (Brissaud et Lereboullet) and from local tumor formations.

The condition is usually progressive to some extent but after a time it becomes stationary without special treatment. Apparently there is no hope of a return to normal and treatment is without effect.

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Facial Neuralgia.—See *Neuralgia*.

Facial Paralysis.—*Synonyms:* Bell's Palsy, Prosoplegia. The muscles of the face, like all other muscles, may be impaired in their function, through lesions in the muscles themselves, in the nerve supplying them or in its cells of origin, in their cortical area of representation or at any point in the course of the fibers from the motor cells of this cortical area through the centrum ovale, internal capsule, crus and pons to the facial nerve nucleus, Since, however, lesions either in the muscles themselves, in the cortex or in the motor tract below the cortex, as a rule, give rise to symptom-complexes of which the facial involvement is only a part, it is customary in the description of facial paralysis to study only lesions of the facial nerve and of its nucleus, considering the paralysis from other sources only in so far as is necessary for differential diagnosis. From this point of view, the disease would fall naturally under the general head of neuritis, though, since it is not in itself fatal, opportunities to study its pathological anatomy are rare and in many cases lesions of the nerve nucleus cannot with certainty be excluded.

Anatomy.—The facial muscles with the exception of the levator palpebræ superioris are supplied by the seventh cranial nerve, which also innervates the stylohyoid, the posterior belly of the digastric and the stapedius muscles. While it was formerly taught that the facial nerve was purely motor in its function, the occurrence on it of a ganglion (the geniculate ganglion) marks its analogy with the spinal nerves and J. R. Hunt has shown that it contains sensory fibers which come from a small somewhat cone-shaped area including the skin of the external auditory canal and part of the outer ear. It also contains fibers passing through the great superficial petrosal nerve to the lacrymal gland, fibers passing by way of the chorda tympani nerve to the salivary glands and in part of the [illegible] from the anterior two-thirds of the tongue, entering the facial by the [illegible] Fallopian canal, leave it again [illegible] petrosal nerve, to pass into the [illegible]. The motor fibers of the facial nerve arise from a large nucleus situated deep in the [illegible] near its junction with the [illegible], the fibers pass dorsalward and forward, gradually converging, and, making a sweeping curve, [illegible] ventralward and backward, to emerge at the [illegible] nerve just below the pons on the lateral aspect of the medulla.

The facial nucleus is connected with the other cranial nerve nuclei by association fibers, especially closely with the eye muscle nuclei as the eye and facial muscles must frequently act synchronously. It has also connection with the nuclei of the optic thalamus so that mental states are reflected in the facial expression, more or less involuntarily and automatically.

Pathology.—While opportunities to examine the affected nerve have been infrequent, Minkowski, Dejerine and Theohari, and others have been able to show that in the ordinary type of facial paralysis (the so-called "rheumatic" paralysis attributed to "cold") there is a neuritis of the parenchymatous variety, affecting particularly the peripheral parts of the nerve. Changes in the nerve cells of the nucleus of the nature of the so-called axonal reaction have also been observed.

Etiology.—The facial nerve is susceptible to the action of the various causes tending to produce neuritis in general and which will find mention under the proper heading. But while these causes may act as predisposing, there are locally acting factors which seem to play the chief rôle in determining an attack of facial paralysis. In infants delivered with the forceps, the pressure of the blades upon the side of the head sometimes injures the facial nerve and is translated as a paralysis of the muscles on that side. Mumps and cervical adenitis occasionally involve the facial nerve, but by far the most common local cause is disease of the middle ear or of the mastoid cells, which may spread to the facial nerve. Exudations upon the base of the brain, syphilitic gummatous meningitis which involves the nerve, and the pressure exerted by a brain tumor may cause facial paralysis, as may also fracture at the base of the skull or bone disease from any cause. The great majority of cases, however, are attributed to "cold" often as draft blowing upon the part. "Vague and unsatisfactory as this conception is " (Bing) we cannot quite get away from it and we can only suspect that the refrigeration, by weakening resistance of the nerve paves the way for the action of some toxic or infectious agent. A history of exposure to cold has been found by those who have investigated the subject in from forty-five to seventy per cent. of cases. It has been suggested by Philip that a disproportion between the size of the nerve and that of the stylomastoid foramen might well play a part by making the nerve more susceptible to influences which tend to cause it to swell. The facial nerve is occasionally involved in multiple neuritis.

Symptoms.—Since in facial paralysis the muscles on the affected side cannot functionate, it presents a characteristic mask like expression, the nasolabial fold is obliterated, the forehead cannot be wrinkled or the eye closed (lagophthalmus), the ball being drawn up under the lid upon attempts to close the eye. Winking no longer occurs, the lower lid is not closely approximated so that the tears may run down on the face, and the conjunctiva frequently becomes inflamed. Through the [illegible] affected side hangs down and the whole face may appear to be drawn to the opposite side. There is lack of the normal play of expression, the [illegible]

on the affected side does not distend upon forced breathing and the cheek sometimes flaps. The patient cannot purse the lips or whistle and since the buccinator does not act, the food cannot be moved around properly but accumulates under one cheek and the patient has to hook it out with his finger. The pronunciation of labials is often indistinct. The tongue may appear to deviate, but usually this is more apparent than real being due to the drawing to one side of the mouth. Occasionally, however, there is an actual deviation due to the paralysis of the muscles attached to the hyoid bone which then drops down on the affected side. On account of weakness of the stylohyoid and digastric the base of the tongue may also stand lower than normal on the affected side. While in neuritis of the facial nerve, the motor symptoms always predominate, often are the only ones, from the complicated make up of the nerve, sensory and secretory anomalies occasionally occur. Pain located in or about the ear, is by no means uncommon, while loss of the sense of taste over the anterior two thirds of the tongue if looked for, can be sometimes detected, though the patient may be unaware of the defect. Abnormally acute hearing and sensitiveness to the deeper tones is due to the occasional involvement of the nerve to the stapedius muscle, through the paralysis of which, the drum membrane is allowed to vibrate too freely, while anomalies of the salivary and of the tear secretion are a result of the occasional involvement of the nerve in that part of its course, in which it contains fibers supplying these respective glands.

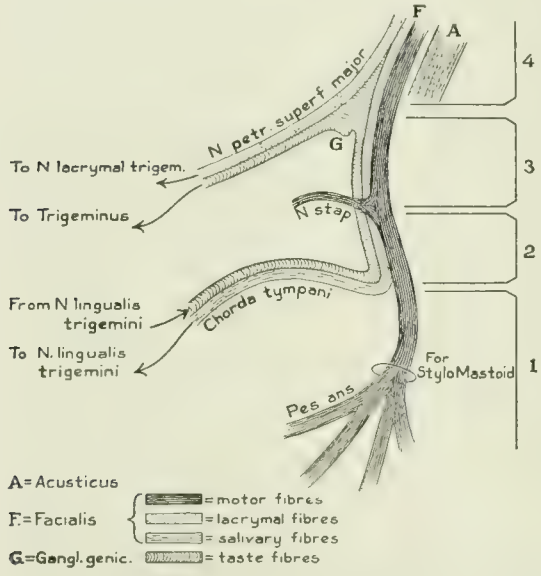

Fig. 2351.—Plan of the Course of the Different Kinds of Fibers of the Facial Nerve. (After R. Bing.)

The accompanying diagram (Fig. 2351) will show what symptoms may be expected in lesions involving the nerve in different parts of its course. Thus: A lesion in the portion of the nerve path labelled 1, will produce paralysis of the facial muscles more or less extensive. In 2, paralysis of the facial muscles, loss of sense of taste on the anterior two-thirds of the tongue, interference with the secretion of saliva. In 3, paralysis of the facial muscles, taste and salivary disturbance, abnormally fine hearing (hyperacusis). In 4, facial paralysis, no taste disturbance, salivary anomaly, hyperacusis (except in cases in which the auditory nerve which lies in immediate proximity to the facial in this part of its course is involved, when there is of course deafness), interference with the tear secretion.

In facial paralysis there is usually disturbance in electrical reactions, varying from slight quantitative reduction of irritability to complete reaction of degeneration. In cases which do not recover the muscles atrophy in time and may undergo a secondary contracture which makes it appear at first sight that the paralysis is on the sound side, but attempts at movement show at once which muscles are really affected. Facial paralysis generally develops quite rapidly, reaching its acme in a few hours or days. The milder cases may recover within a month or six weeks, the more severe last six months or more.

Diagnosis.—The symptoms of facial paralysis are plain enough; the problem is to diagnose the seat of the lesion. Facial paralysis can, and occasionally does, occur as a result of lesions either in the cortex, or in the motor tract between this point and the nucleus of the seventh nerve (supranuclear lesions). In the great majority of instances, however, lesions in this part of the brain are sufficiently extensive to cause additional troubles, so that the paralysis of the face is only one of a group of symptoms. Diagnostic of a supranuclear lesion, however, are the following: The muscles of the forehead usually act more or less normally (the muscles of each side have representation on both sides of the brain), there is not complete paralysis of the orbicularis palpebrarum so the eye can be closed, winking is possible, the facial muscles can still reflect the play of the emotions though they cannot be contracted voluntarily and the electrical reactions are unaltered. Though an isolated lesion of the facial nerve nucleus can occur and could hardly be differentiated from one involving the nerve itself, such an occurrence is extremely rare, in the great majority of instances some of the other nuclei of the bulb, especially that of the sixth nerve, being also affected. From its location in fact, this latter nucleus can hardly escape when the seventh nerve is involved. Involvement of the lower nuclei gives the symptoms of bulbar paralysis, while if there is hemorrhage or softening, in addition to facial paralysis, there is apt to be motor or sensory disturbance of the opposite side of the body. In disease at the base of the brain there will almost certainly be involvement of some of the other cranial nerves besides the facial, possibly of the motor tracts also.

Prognosis.—In supranuclear and nuclear lesion and in involvement of the facial nerve in disease at the base of the brain, the prognosis depends upon the amenability to treatment of the underlying condition. In neuritis of the facial nerve much depends upon the severity of the disease. In cases secondary to ear disease with extension to the temporal bone the outlook is unfavorable as there is apt to be involvement of the nerve in the general destruction. In the ordinary rheumatic neuritis—or that attributed to cold—the prognosis is as a rule favorable. If there is complete R. D. we may be sure that recovery will not be complete for a number of months if it occurs at all, though according to Starr, it may persist for a year or more and yet the case may ultimately recover. If there is partial R. D. the case may get well in two or three months, while cases showing only slight change in the electric reactions will probably recover in three or four weeks.

Treatment.—In cases due to intracranial disease, the treatment will be that of the underlying condition and the only cases in which any result from a positive therapy could be expected are those clearly dependent upon syphilis. In those cases in which the lesion is in the nerve itself and no definite etiological factor other than the rather indefinite one of exposure to cold can be made out, it is advised, if the case is seen within the first day or two, to put on a small blister just back of the ear. Salicylic acid preparations as aspirin, salicylate of sodium, etc., may also be ad-

ministered and will often relieve the pain which is apt to be present at this stage. In the later stages potassium iodide in moderate doses and strychnine are recommended as tending to favor absorption of exudations and return of excitability. As soon as all irritative symptoms have subsided, the use of electricity should be begun, the form of current which will cause the paralyzed muscles to contract being applied, though in general, galvanism is of most use in restoring the contractility and in keeping up the nutrition of the affected muscles. There should be daily applications for ten or fifteen minutes and in the mean time the patient should massage the face several times a day. In muscles which begin to show a tendency to contracture the electric treatment should be given up as it favors this last process. In chronic cases which remain stationary for a year or more, the advisability of surgical measures should be seriously considered. Taylor and Clark have reported some good results from the anastomosis of the facial with the hypoglossal nerve.

CHARLES LEWIS ALLEN.

Facial Spasm.—See *Spasm.*

Fainting.—See *Syncope.*

Falkenstein.—There is nothing remarkable about the climate of Falkenstein which would warrant its notice as a health resort. It has, however, become widely known through the renowned Dr. Dettweiler who was the head for many years of the Falkenstein Sanatorium which did so much to popularize sanatorium treatment and proved that pulmonary tuberculosis could be successfully treated in an indifferent climate. "I can cure tuberculosis in any climate, for it is method rather than climate," said Dettweiler.

Nine miles out of Frankfort is the picturesque village Cronberg in the Taunus Hills, where resided the late Dowager Empress of Germany. A walk of about forty minutes up the hill from here brings one to the tiny village of Falkenstein commanding an extended view over the valley of the Main and Frankfort in the distance. Here is situated Dettweiler's Sanatorium in a location protected on the North, West, and East at an elevation of 1,400 feet above sea-level.

The sanatorium building is of the [illegible] generally obsolete, but Dettweiler by his method and personality produced excellent results [illegible]

The climate is that of Central Germany, its principal characteristic being a pure atmosphere free from dust; only about half the days in the month are sunny.

In spite of rain, fog, or snow, and of cold even to 12° F. below zero, Dettweiler insisted upon his patients remaining in the open-air galleries from seven to eleven hours daily, and for the greater part of the time at rest. Dettweiler was so insistent upon *rest* in the open air that his method was called the "rest treatment" (Ruheluft-Kur), and later experience has confirmed to a great degree his contention that tuberculosis patients, at whatever stage or condition of the disease, do best with a great deal of rest.

Before admission to the Sanatorium, each patient was carefully studied, not only his physical condition but his temperament and will power, and his intelligent and willing cooperation obtained. His plan of life was then arranged in all its details. He was constantly under the eye of the physicians who were always present at the principal meals. Great care was taken with the diet, for Dettweiler used to say that his "pharmacy was his kitchen." To [illegible] skilled watchfulness and care, the hygienic-dietetic

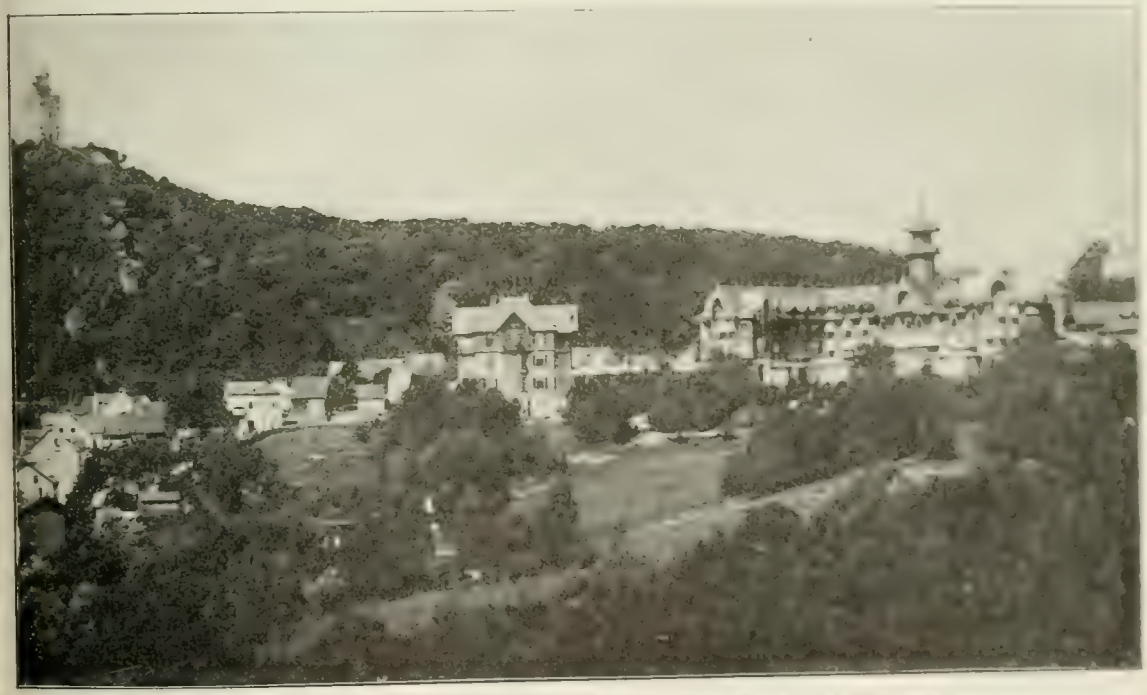

FIG. 2352.—Dettweiler's Sanatorium at Falkenstein, as seen from Adelheidsen

measures and the hyperaeration, with [illegible] personality of the master, Dettweiler, is due the success he attained. It is interesting to note the daily routine for an average patient as learned by the writer on a visit to Falkenstein some years ago:

7 A. M. Rubbing—dry or wet [illegible]

8 A. M. Breakfast, consisting of coffee, tea, cocoa, chocolate, with bread, butter, honey, and milk.

Until 10 A. M. Rest in the reclining chair.

10 A.M. Second breafast (according to the European custom) of bread, butter, milk, and soup, and, in certain cases, a little alcohol.

10.30 A. M. to 1 P. M. The rest treatment again.

1 P. M. Dinner, consisting of soup, fish, vegetables, several kinds of meat, fruit, dessert, and coffee.

2 to 4.30 P. M. Rest again.

4 P. M. Milk.

4.30 to 7.30 P. M. Rest or walking.

7.30 P. M. Supper, consisting of soup, hot and cold meats, salads, preserves.

After supper the rest treatment until 10, with milk at 9.

10 P. M. Retire.

Dr. Dettweiler, who was a consumptive himself in early life, was at first associated with Brehmer, the father of the sanatorium treatment, at Goebersdorf, and later he established his famous institution at Falkenstein. Brehmer and Dettweiler will always be regarded as the two great pioneers in the modern open-air sanatorium treatment of tuberculosis. He was a man of great simplicity and sympathy, inspiring enthusiasm and love in his patients, who in consequence readily yielded to his will and guidance. "In him," as said by one who knew him, "reason, science, and long experience were correlated into action by discrimination, adaptability, sympathy, and unbending will. In both the senses in which this term can be employed he was a presiding genius."

EDWARD O. OTIS.

Fallopian Tubes.—See *Oviducts.*

Fallopius, Gabriel.—This celebrated Italian anatomist, the contemporary of Vesalius and of Eustachius, was born at Modena in 1523. His name is sometimes written Falloppius or more commonly, in the Italian form, Falloppio, and much ink has been wasted in the controversy between those who argue for one p and those who would double this letter; the dispute may be compromised by spelling the Latin name with one p and granting two to the more modern form. He studied anatomy at Padua under Vesalius, who had been appointed to that chair at the age of twenty-three, and he himself when but twenty-four

FIG. 2353.—Gabriel Fallopius.

years old was appointed professor of anatomy at Ferrara. After teaching there for a time he answered a call to the University of Pisa, and later assumed the chairs of anatomy, surgery, and botany at Padua. Although the name of Fallopius is associated with the oviducts, his most important work was done in connection with the organ of hearing, in which he described the fenestra ovalis, the communication of the mastoid cells with the tympanum, and the lamina spiralis. The terms aquæductus Fallopii, the canal giving passage to the facial nerve through the petrous portion of the temporal bone, Fallopian hiatus, the opening in the petrous bone giving passage to the great superficial petrosal nerve, and Fallopian arch or ligament, more commonly called Poupart's ligament, also serve to perpetuate the name of this great anatomist. He described the seminal vesicles and many of the structures of the female generative organs.

Fallopius died at Padua, October 9, 1562, at the early age of forty-one years. Most of his writings were published posthumously; among them were: "Observationes Anatomicæ," Venice, 1561; "Commentarius in Hippocratem de Vulneribus Capitis," Venice, 1566; "Expositiones in Galeni Librum de Ossibus," Padua, 1585; "De Morbo Gallico Tractatus," Venice, 1564. His collected works were published in three volumes at Venice in 1584. T. L. S.

Fannia.—A genus of flies, *Diptera.* The larvæ of *F. canicularis, F. desjardensii,* and other species are parasitic in the human intestine. See *Insects, parasitic.* A. S. P.

Farcy.—See *Glanders.*

Farmville Lithia Springs.—Prince Edward County, Virginia.

POST-OFFICE.—Farmville. Boarding-houses.

ACCESS.—Via Norfolk and Western Railroad to Farmville, thence one-quarter mile to springs. Farmville is a thriving town, located fifty-five miles east of Lynchburg and seventy-two miles south of Richmond. The railroad depot is within convenient walking distance of the springs, but carriages are at hand for all those who prefer to ride. There are many features of interest in this historic region. The springs are beautifully situated about 550 feet above the sea-level. The surrounding country is very pleasing to the eye, and on every hand the visitor is met by names and locations of familiar memory. Nor far from the springs are found the battle-fields of Chancellorsville, Appomattox, Rapidan, Five Forks, and others of lesser note. The climate here is bracing, the temperature ranging from 40° to 50° F. in winter and from 80° to 90° F. in summer. The following analysis of Farmville lithia-water is by Prof. E. T. Fristoe, professor of chemistry at Columbia College, Washington:

ONE UNITED STATES GALLON CONTAINS:

Solids.	Grains.
Sodium chloride	5.30
Sodium sulphate	3.59
Potassium sulphate	0.18
Calcium sulphate	1.81
Lithium bicarbonate	3.76
Calcium bicarbonate	1.33
Magnesium carbonate	2.71
Ferrous carbonate	1.26
Manganous carbonate	Trace.
Alumina	2.52
Silica	3.92
Iodine	Trace.
Sulphuric acid	Trace.
Organic matter	Small quantity.
Total	26.38

Carbonic acid gas, 74.20 cubic inches.

It will be observed that this water contains a fair proportion of the bicarbonate of lithium. It is also abundantly charged with carbonic acid gas, and contains sufficient sulphate of sodium to give it a mild laxative action. The water has come into wide use as a corrective of the so-called uric-acid diathesis, and is sold in all parts of the country. Its best effects have been observed in gout, rheumatism, gallstones, renal and vesical calculus, Bright's disease, dyspepsia and skin diseases. The iron in the water gives it also

excellent properties as a ferruginous tonic. Besides the lithias, there are many other mineral springs. Among these are Magnesia, Sulphur, Iodine, Alum, Iron, Arsenous chalybeate, and Sweet Water Springs.

EMMA E. WALKER.

Fascia.—Portions of the original connective tissue of the body which have become condensed into sheets or bands, by reason of the stress from muscular action which that tissue has undergone.

In Fig. 2354 let A A be a segment of the skeleton, and B and C other neighboring segments, the original connective-tissue network in which they are laid down being indicated by the oblique faint lines. Let now a muscle be developed in this tissue, with its long axis between the points A and B, its contraction tending to make these points approach each other. The original connective tissue of the region interpenetrates the muscle, and remains permanently part of it as its endomysium, clothing the separate bundles of fibers. It is evident that the contraction of this muscle will cause a stress upon the surrounding tissue, and condense it into the form of a sheath, separating the more movable from the more stationary portions, as indicated by the dotted line. Let another muscle, as A C, develop contiguously, it will also have its appropriate sheath of condensed connective tissue, which, along the line of contact with its neighbor will be thicker than elsewhere, it here receiving stress from two distinct sources. The degree

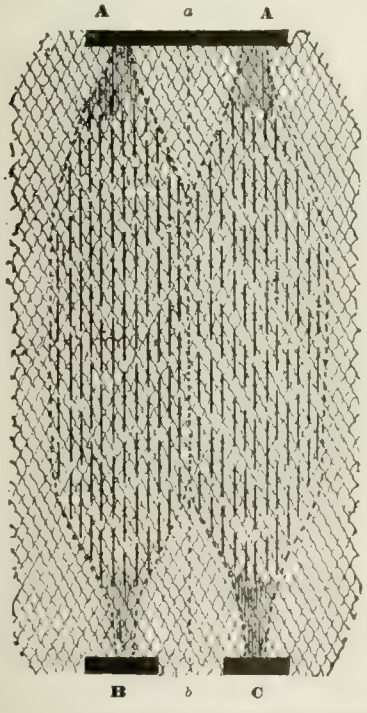

FIG. 2354.—Diagram showing the Formation of Fascia from Connective Tissue.

of thickness of the separating fascia will depend upon the degree of independence of the muscles. If they usually act together, it will be thin; if one is frequently inert while the other moves, it will be thicker; and if, while one is acting on the point B, the other is always inert or stretched, as must, for example, necessarily happen when B is on the flexor side of a limb, while C is on the extensor side, the fascia becomes so thick and strong that it is named by some authors an "intermuscular ligament." It is obvious that the thickening will extend from one [illegible] the direction of the line a b. [illegible] fore appear as a well-marked [illegible] ing the shining appearance of a [illegible] reduced to a loose web of [illegible] tive tissue. Its development [illegible]

The fascia immediately enclosing the muscle is known also as its sheath or perimysium. Those lying between the muscles are called [illegible] septa, and in a number of situations, where the peculiarities of the region have determined a band-like form, such bands have received special names as ligaments. Arising like the bones from special conditions of the connective tissue, the two are structurally continuous, the periosteum of the bones blending inseparably with the fascia, and fibers from thence passing through and through the osseous tissue. The lines and ridges on the bones indicate the insertion of fascia, and may be considered as very small extensions of the process of ossification into those structures. In pathological conditions this is sometimes excessive, sheets of fascia ossifying like the ossification in membrane which occurs in the vault of the cranium. From this intimate union with bones it necessarily follows that fasciæ are intimately connected with the ligaments of joints, which are also connective-tissue structures arising in a way essentially similar to that of fascia; and, indeed, they cannot structurally be distinguished from it (see Arthrology). As it is at or near the joints that a great number of muscles end, the fascia there becomes continuous with the ligaments.

The vessels and nerves of a region, being developed within the connective tissue, are naturally found between the muscles and within the layers of the fascia, which not only gives them an investment, but affords a valuable guide to them in surgical operations.

If the fasciæ of the body could be made to stand out independently and distinctly there would, therefore, be seen a series of partitions passing between separate portions of the skeleton and arranged both radially, connecting the skin with the bones and deeper structures, and concentrically, separating the layers of muscles from the skin and from each other. The thinner partitions separate single muscles, the thicker ones muscle-groups.

Fascia is distinguished as superficial and deep, the superficial lying next the skin, being looser in texture, and containing (except on the scrotum and eyelids) a considerable amount of subcutaneous fat (panniculus adiposus), which never entirely disappears even in great emaciation. The superficial fascia may usually be separated into layers, and where considerable strain is put upon it, as at the groin, these may become quite thick and well marked. In the face, neck, and scalp, and occasionally in other situations, muscular fibers may be found within it, seeking insertion upon the skin. These are much more developed in some mammals than in man, forming the so-called panniculus carnosus. The superficial vessels and nerves run in its deeper portions.

The deep fascia affords, in many cases, origin for muscular fibers, and when this is of considerable extent it is called an aponeurosis, from the [illegible] usually covers, or is continuous with, the tendon of the muscle.* Bichat divided aponeuroses into two varieties, those of investment and those of insertion. The first usually contain elastic fibers, which adapt the sheath to the muscle during its changes of form due to contraction. If the muscle atrophies, however, the sheath ceases to be [illegible] the causes of the [illegible] is the relaxed condition of the muscle-sheaths. Tension of the sheaths is also effected by the contraction of associated muscles. This is quite general through-

* The Greek word [illegible] as to nerve

out the muscular system, and Bardeleben[1] has pointed out that at least two-thirds of the muscles have fascial insertions; yet there are some muscles which seem to be specially assigned to the work, and to such the name of tensors of the fascia is given. It appears to be a general rule, that the usual action of a proximal segment puts into a somewhat tense condition the fascia of the succeeding segment, thus preparing the way for its muscles to act to the best advantage. In the upper limb, for instance, the pectoralis major renders tense the fascia of the upper arm covering over the biceps and other muscles, the biceps in its turn stretches the fascia of the forearm, one of the muscles of which, the palmaris longus, renders tense the fascia of the palm. A similar arrangement may be made out in the lower limb.

In some situations aponeuroses may stretch across the surface of other muscles, forming tendinous arches attached at either end to the skeleton, and from these muscular fibers arise. Examples of this are seen in the levator ani, and the lumbocostal arches of the diaphragm.

Fasciæ have an important function in determining the direction of muscular action, by confining the muscle in a definite manner. This may be but slight, as in the sternocleidomastoid muscle of the neck, which is held forward by its investment in such a manner as to pull to more advantage upon the head, and at the same time prevent any pressure upon the great vessels of the neck; or it may be very considerable, as in the case where a special band of fascia holds down a portion of the muscle, so that the direction of the applied force is notably changed. Examples of this occur in the omohyoid muscle of the neck, and near the hand and foot, where special thickenings of the fascia, called annular ligaments, confine and change the direction of the tendons passing down from the limb. There is also here a special investment of the tendons derived from the deep fascia, and called a synovial sheath (see Bursæ).

The surgical importance of fascia is considerable. Composed of a tissue of low vitality, it is not readily affected by inflammatory processes, and consequently confines the products of inflammation, such as pus and exudations. These, therefore, usually undermine the tissues along the lines where the fascia is weakest, and may appear at points far remote from their origin. This may also be the case with any gas or foreign body which enters the tissues. Fasciæ are also important by their mechanical qualities, and require to be divided in cases where there is a considerable swelling from inflammation. It is therefore of the first importance to ascertain whether a swelling is under the deeper fascia or superficial to it.

Fascia is especially affected in certain disorders, such as rheumatism. In some cases it undergoes a shortening or contraction, which causes marked deformity, especially in the fingers and the feet. When a limb has been for a long time flexed the fascia shortens and holds it in that position.

Morphologically, fascia may be of importance as indicating the position of muscles of which all other vestiges are lost. Some remarkable examples of this have been shown by Sutton,[2] who has found, by investigating the peculiarities of fascia, many vestiges in man of a musculature now possessed only by the lower animals.

Bearing in mind the origin of the fasciæ, it will be seen that a proper understanding of them depends entirely upon a knowledge of the muscle-groups and their relative importance. Each group has fascia separating it on either side from the other structures. A proper comprehension of this greatly simplifies a study often needlessly complicated. It remains to point out briefly the characteristics of different regions.

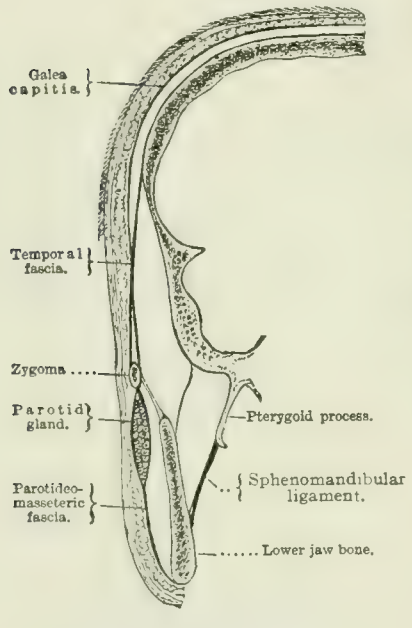

Fig. 2355.–Frontal Section through Left Temporal Region, showing the Relations of the Fascia.

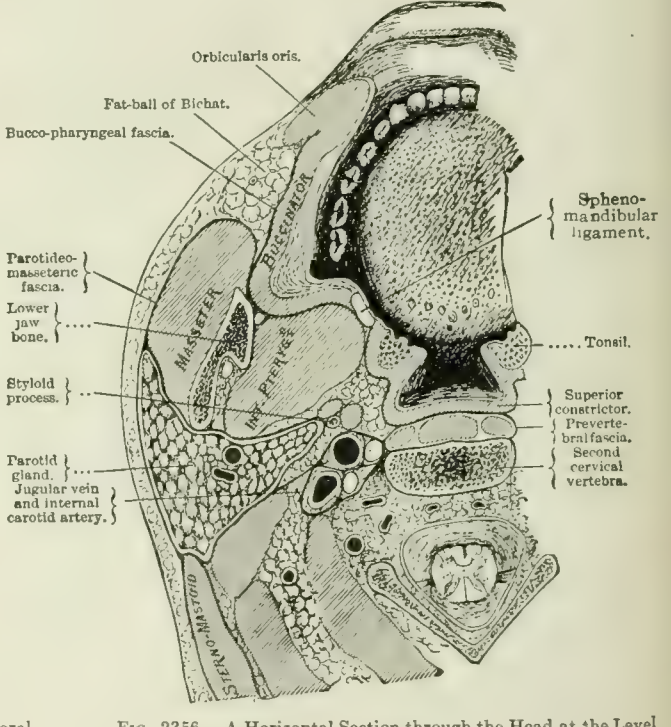

Fig. 2356.—A Horizontal Section through the Head at the Level of the Lower Teeth, showing the Relations of the Fascia.

Head.—The crown of the head is covered with the galea capitis, a fascial investment forming the intermediate tendon between the two portions of the epicranius muscle. Like that muscle it properly

belongs to the superficial fascia. (Fig. 2355.) It is continuous at the sides with the temporal fascia. The separability of this sheet, united to the pericranium by lax connective tissue, permits the scalping practised by the Indians. The scalp has been gashed in childbirth in ignorant mistake for the membranes, and the skull extruded through the wound, the child's head being born peeled like an orange (Agnew). A similar case is recorded by Erichsen, where, from a fall, a sailor had the entire scalp peeled off, but yet made a good recovery. Suppuration beneath the galea may be very extensive. Richet describes the entire scalp from one ear to the other raised by a suppurative process. It would be limited in front by the orbital line, behind by the superior curved line of the occipital bone, on the sides by the zygomatic processes. The other muscles of the face developed in the superficial fascia have no special sheets of fascia that are readily demonstrable.

The temporal fascia belonging to the deeper muscles (Fig. 2355) covers over the temporal muscle, passing from the temporal line to the zygomatic arch. It is so thick and strong that it feels like a bone under the skin. Below the arch the muscle and its tendon are separated from the masseter only by a very thin septum. Pus under the temporal fascia burrows down along the tendon.

The parotideomasseteric fascia (Figs. 2355 and 2356) is properly a process of the cervical fascia, with which it is continuous behind. It confines the masseter muscle, passing from the zygomatic arch to the mandible. It is very thick and strong, and fluctuation under it is felt with difficulty. As it confines the underlying parts, great pain is felt in any inflammation of the parotid from the presence of the inflammatory products. Under the parotid a layer of fascia passes behind the mandible to the pharyngeal muscles.

The buccopharyngeal fascia (Fig. 2356) covers the superior constrictor behind and the buccinator in front, the division between the two being a band which passes from the hamular process of the sphenoid to the mylohyoid ridge of the mandible, and is called the pterygomandibular raphé. Before leaving the head there should be mentioned a delicate fascia which occurs in the orbit, surrounding the ocular muscles and ensheathing the globe of the eye so that it rolls within it as in a socket. This is known as the fascia bulbi. It has a prolongation on each of the muscles.

Neck.—The cervical fascia has enjoyed a rather unenviable reputation. Malgaigne speaks of it as the anatomical Proteus that takes different shapes according to the fancy of the observer. Viewed according to the principles above set forth, it is not, however, of any great complication, as it strictly follows the laws therein set down. It is usual to describe first the superficial sheets, but the more logical method is to commence with those first formed, adding those of later development. Considered, therefore, from this point of view, the following layers may be made out.

First, the prevertebral layer, enclosing the vertebral group of muscles constituted by the longus colli et capitis and the rectus capitis anterior in front, and the semispinales capitis et colli, the splenius, the levator scapulæ, scaleni, and others, laterally and behind. It is limited above by the occipital bone, and runs below over the longus colli muscle into the thorax. It is strong, offering considerable resistance to suppurative action. Behind the spine (fascia nuchæ) the intermuscular septa enclose considerable fat in their interstices, and this is the favorite seat of carbuncle. Laterally investments are sent to cover the great vessels of the neck, and as the muscles from the postvertebral set detach themselves to go to the ribs (scaleni) or scapula (levator scapulæ), the fascia ensheaths them also, and passing down on the subclavian vessels and the brachial plexus forms the axillary sheath, and joins the [illegible]

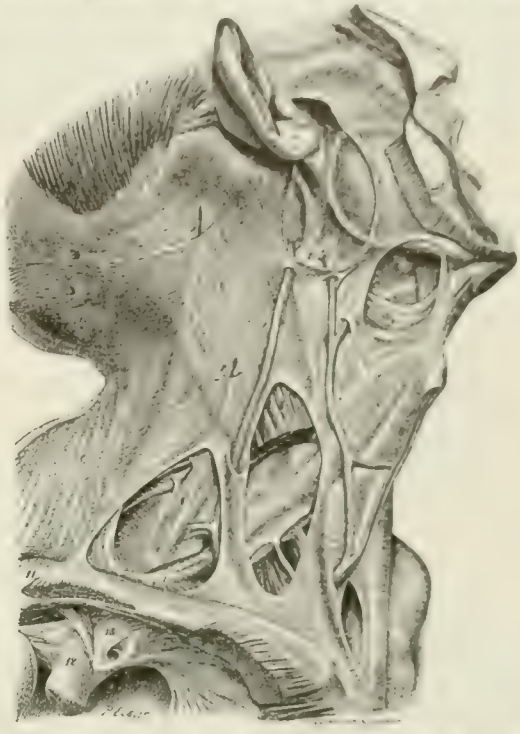

Fig. 2357.—Fascia of the Neck. 1. Subcutaneous space; 2. parotid space; 3. sternocleidomastoid muscle; 4. supraclavicular fossa; 5. suprasternal space; 6. external jugular vein; 7. supraclavicular fossa; 8. median vein of the neck; 9. occipitalis minor nerve; 10. auricularis magnus nerve; 11. [illegible] muscle; 12. coracoid process; 13. coracoclavicular tissue. (After Eisler.)

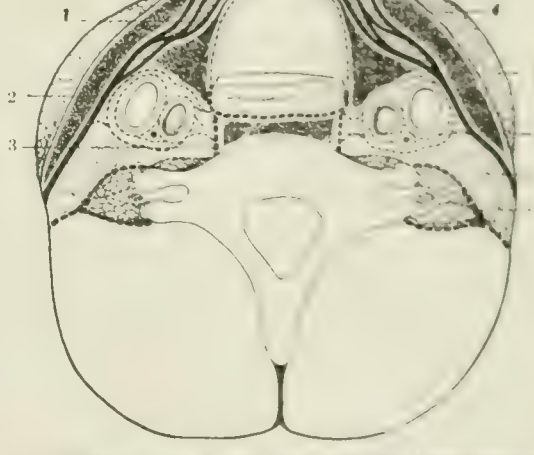

Fig. 2358. Fascia of the Neck [illegible] Spaces injected, seen on C[illegible] Larynx. 1. Visceral sheath; 2. [illegible] fascia; 4. space between the [illegible] 5. previsceral space; 6. [illegible] adipose tissue; 8. sheath; [illegible] Charpy.)

fascia coracoclavicularis. An [illegible] between the spine and the prevertebral [illegible]

that fluids penetrate downward as far as the bifurcation of the trachea, that the tissues around the esophagus are completely infiltrated, and that outwardly they pass under the clavicle into the axillary space.

Second, the visceral layer. The viscera of the neck include the esophagus, with its continuation of pharynx and mouth, the trachea, larynx, and thyroid gland. Over these a layer of fascia (fascia pharyngo-basilaris) passes, attached above to the occipital bone,

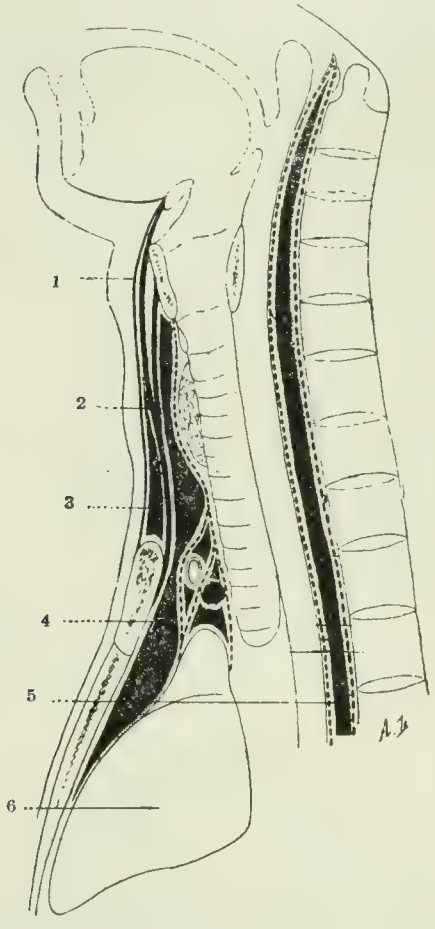

Fig. 2359.—Fascia of the Neck with the Interaponeurotic Spaces Injected and Seen on Longitudinal Section. 1. Shoulder-girdle layer; 2, visceral layer; 3, suprasternal space; 4, pre-visceral space; 5, retrovisceral or prevertebral space; 6, pericardium. (After Poirier et Charpy.)

basis cranii, and pterygoid process, forming the stylo-mandibular ligament, continuous with the bucco-pharyngeal fascia mentioned above, passing down along the mylohyoid ridge of the mandible to the middle line. Below it is attached to the posterior border of the sternum in front, and descends into the thorax over the esophagus, trachea, and great vessels, becoming continuous with the fibrous layer of the pericardium, and finally ending as the central tendon of the diaphragm (see Fig. 2360). This peculiar downward extension is determined by the so-called descent of the heart (see *Diaphragm*). Laterally it unites with the prevertebral fascia to form an investment for the great vessels of the neck, the common carotid, the internal jugular vein, and the pneumogastric nerve, and is firmly united to the posterior border of the clavicle. In the lower part it is very thick and strong, and its investment of the vessels is so firm that it holds them open, so that at every inspiratory act the dilated thorax exerts an aspiratory force upon them, assisting greatly the descent of blood through the jugular from the sinuses of the brain. This same fact makes a wound to vessels in this region very dangerous, as, in such a case, the air is usually drawn into the veins and the heart, and death results. The fascia has a tensor in the omohyoid muscle, which is invested by it and held in place by a process attached to the first rib. As the fascia stretches immediately over the pleuræ, where it clothes the apices of the lungs behind the clavicles, it was believed by Richet that the omohyoid, by its contraction, assisted to expel air from the upper part of the lungs. It is questionable whether this be of any importance. Any effusion between this layer and the prevertebral fascia may pass downward into the posterior mediastinum, and as the connective tissue there is quite lax, it may push through and do considerable damage.

Third, the shoulder girdle layer, enclosing the external muscular mantle. This mantle is originally a broad sheet, which encloses the limb of the fetus as it buds out laterally from the trunk. It becomes differentiated, above, into trapezius and sternocleidomastoid; below into latissimus dorsi, deltoid, and pectoralis major, the shoulder girdle developing transversely within it. In front there are no muscles belonging to this layer, but the muscles inserted upon the hyoid bone above and below, which are really a secondary visceral set, appear upon the surface. A layer of fascia (lamina superficialis) starts from the

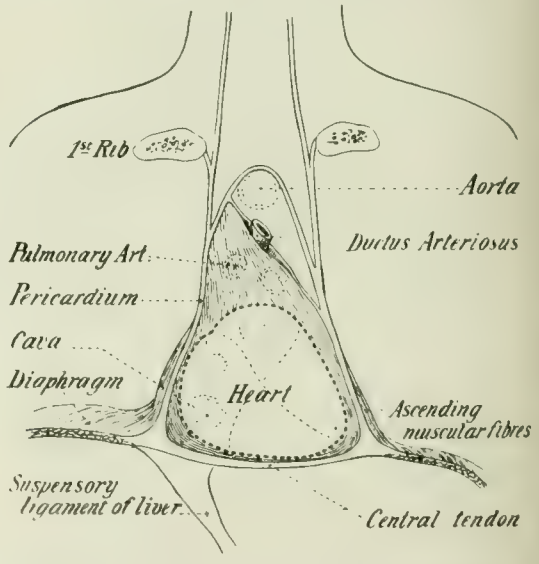

Fig. 2360.—Diagram showing the Continuity of the Visceral or Deep Layer of the Cervical Fascia with the Pericardium and Diaphragm.

ligamentum nuchæ behind, splits to enclose the trapezius, uniting again to cover over the posterior triangle of the neck; then it splits again to receive the sternocleidomastoid, again reunites, and passing over the hyoid muscles, joins the similar sheet from the opposite side. It is a firm, close layer. Above, it is attached to the edge of the mandible enclosing the submaxillary gland; below, there is a splitting just above the sternum, to receive the anterior jugular veins. One sheet is attached in front and one behind the sternum. The sternal portion of the sterno-cleidomastoid lies between these. It is attached to the anterior border of the clavicle and the spine of the scapula. The stylomandibular ligament is a thickened portion extending from the styloid process to the angle of the mandible, between the parotid and sub-

maxillary glands. The digastric muscle and its congener, the stylohyoid, act as tensors of this facia in the upper part; and they thus effect a discharge of the secretion of the submaxillary gland. Below, the sternocleidomastoid makes it tense, holding it forward toward the middle line. It is pierced above the clavicle by the external jugular on its way to the subclavian vein, and by numerous nerves and small vessels. The figure will show that it is continuous with the deeper fascia at certain points, as, for instance, in the posterior triangle and over the sheath of the great vessels.

Abscesses between this layer and the one last mentioned do not often occur. Any effusion would penetrate over the great vessels and behind the sternomastoid into the supraclavicular fossa, and thence break through into the axilla.

Back.—The trapezius, latissimus dorsi, and the rhomboidei have special coverings, but the most important of the investments in this region is the one known as the fascia lumbodorsalis, which is attached on the one side to the spines of the dorsal, lumbar, and sacral vertebræ, on the other to the rib elements, viz., angles of ribs, transverse processes of lumbar vertebræ, and the ilium, forming along the back a tubular space enclosing the sacrospinalis and deeper muscles (see Fig. 2361).

Above, it passes into the fascia nuchæ. Laterally, it becomes the external investment of the intercostal muscles above, and of the abdominal muscles below. It offers a great resistance to pus finding its way

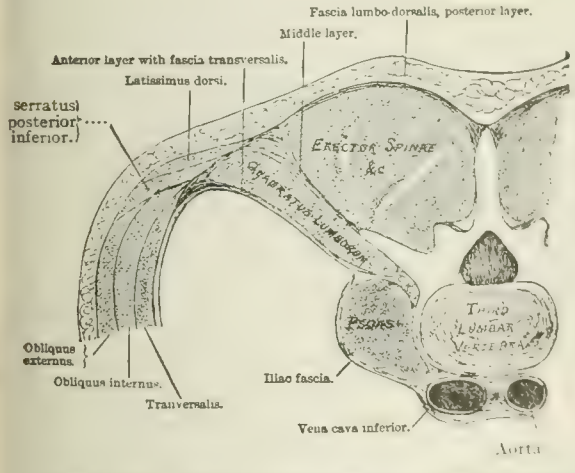

Fig. 2361.—The Lumbar Fascia shown by Horizontal Section through the Muscles of the Back.

outward; when that does occur it penetrates along with the last intercostal artery and nerve, or the iliohypogastric nerve, along a line from the last rib downward. The place shown in Fig. 2361, where the fascia splits to invest the abdominal muscles, is where it is usual to cut it to reach the colon or the kidney.

Abdomen.—The external layer of [illegible] derived, as just stated, from the [illegible]. Between adjoining muscles is the [illegible], which is also derived from [illegible] shown in Fig. 2361. [illegible] invest the rectus abdominis [illegible] line to form a thick aponeurotic layer, the linea alba.

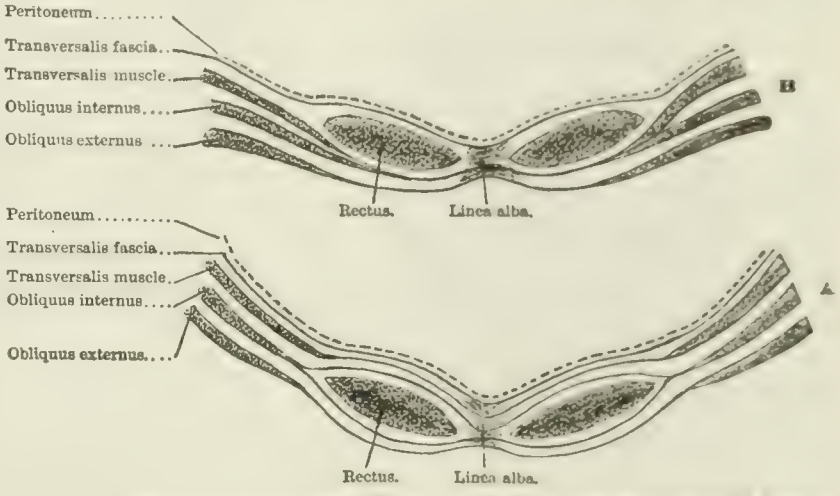

Fig. 2362.—Arrangement of the Abdominal Fascia. A, above the linea semicircularis. B [illegible]

The investment is somewhat different in the upper and the lower parts of the abdominal wall. Above (Fig. 2362, B) the sheath of the internal oblique splits to enclose the rectus, and the aponeurosis of the transversalis passes behind. Below (Fig. 2362, A) everything passes in front except the delicate transversalis fascia which constitutes the real limiting fascia of the whole group internally. This deficiency in the posterior wall of the rectus forms a curved edge with concavity downward, the linea semicircularis. It commences on a level with a line joining the anterior superior iliac spines. Above this, the fibers of the internal oblique and the transversalis take origin from fixed parts and are principally used in strong expulsive efforts; below, they arise from movable parts and mainly aid in respiratory acts, pushing up the viscera from below. The linea semicircularis is, therefore, a more or less sharply defined boundary between the stronger, more energetically active region of the muscles and the weaker, more passive portion.[3] In women who have borne many children, and consequently used the abdominal muscles much in strong expulsive efforts, the fold is thicker and extends down farther.[4] This interpretation is in strict accord with the laws of the formation of fascia, and seems more reasonable than that of Henle,* who supposes the fascia here to be thinner, in order to accommodate the inferior epigastric artery and prevent its compression, or that of Retzius and Henle,* who think it is to accommodate the varying distention of the bladder. Gegenbaur† has, however, pointed out that this area was occupied by the bladder in fetal life before the full development of the pelvis, the bladder being really developed as an extraperitoneal viscus, within the bodywall. This transversalis fascia, which has been mentioned, is a secondary structure which has developed by a thickening of the subperitoneal layer of [illegible] quence of the erect position. Above, it blends with the fascia covering the diaphragm. About the umbilicus it is often thickened [illegible] extent, known as the umbilical fascia. Below, the arrangement of the abdominal fascia is especially important, because of its relation to hernia. Where the muscular tissue ends at the lower part of the

abdominal wall, the several layers of fascia become condensed into a thickened cord which spans from one muscular insertion to the other. This is the inguinal ligament, certain reflections of which have received other names, the firm band attached along

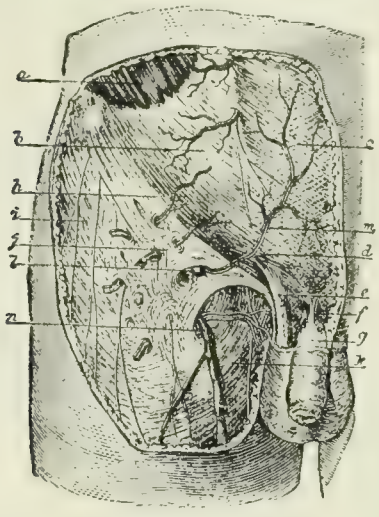

Fig. 2363.—The Outer Layers of Fascia of the Abdomen and Groin. *a*, *b*, The external oblique and its aponeurosis, crossing at *c* with the fellow of the opposite side, at *d* forming the crura of the subcutaneous abdominal ring; *e*, spermatic cord; *f*, *g*, suspensory ligament of the penis; *h*, inguinal ligament.

the pectineal line being called the lacunar ligament; another variable band extending under the external ring to the opposite side, the reflected inguinal ligament. It is here that the spermatic cord in the male, or round ligament of the uterus in the female, passes out (see Fig. 2363).

The transversalis fascia being the innermost layer, becomes partly continuous in front with the fascia over the psoas and iliacus (iliac fascia), and partly joins the anterior portion of the sheath of the femoral vessels. Various portions of it have received different names. Where it passes under the inguinal ligament it is called the deep crural arch; where it covers over the abdominal inguinal ring, the infundibuliform fascia.

The fascia of the posterior wall of the abdomen is known, where it covers the iliopsoas muscle, as the iliac fascia. It follows the muscle as far as the inguinal ligament into the thigh, and is then continuous with the iliopectineal fascia which forms the posterior wall of the crural sheath. Pus arising from caries of the vertebræ usually runs down under this fascia into the leg, and points in the upper part of the thigh just outside the vessels.

Perineum.—In order to an understanding of the perineal fascia, a few words as to the arrangement of the muscles are necessary. These are to be regarded as an apparatus not only for proper muscular functions, but for closing the outlet to the pelvic cavity, forming the floor on which, in the erect position, the main weight of the viscera rests. The pelvic cavity contains the rectum, the bladder, and the internal genital organs, which must have their appropriate apertures, and the musculature and fascia must protect them also. The muscles are arranged, therefore, in two sets, which may be called the diaphragm of the pelvic floor, and the urogenital diaphragm. The first is constituted by the levator ani and the coccygeus; the second by the sphincter of the membranous urethra and the transversus perinei profundus. Outside of these there is a set of superficial muscles comprising the ischiocavernosus, and the transversus perinei superficialis. Each diaphragm and each layer has its appropriate fascia (Figs. 2364, 2365, and 2366). That lining the inner surface of the pelvic floor is known as the pelvic fascia, consisting of the obturator, the pyriformis, and the rectovesical (portions Figs. 2365 and 2366). The obturator and pyriformis fasciæ are simply the perimysia of the muscles of the same name. From the inner surface of the former a thickened arch springs which gives origin to the rectovesical fascia, the internal perimysium of the levator ani, but passing from it on to the prostate gland, rectum, and bladder, forming folds which are known as ligaments of those organs. It is continuous over the middle line, and closes in the pelvic outlet there. Processes from it invest the rectum, the prostate gland, and the vesiculæ seminales in the male, and the vagina in the female.

The levator ani has its external perimysium, a thin layer called the anal fascia (Fig. 2365, 4). This lines the inner side of the ischiorectal fossa.

The urogenital diaphragm is enclosed between two layers of fascia, formerly called the triangular ligament of the urethra or subpubic fascia, being stretched across under the subpubic arch. The superior (posterior) layer is a continuation of the obturator fascia forward over the subpubic outlet. The inferior is firmly attached to the pelvic rami and connected below with the posterior layer (Fig. 2364).

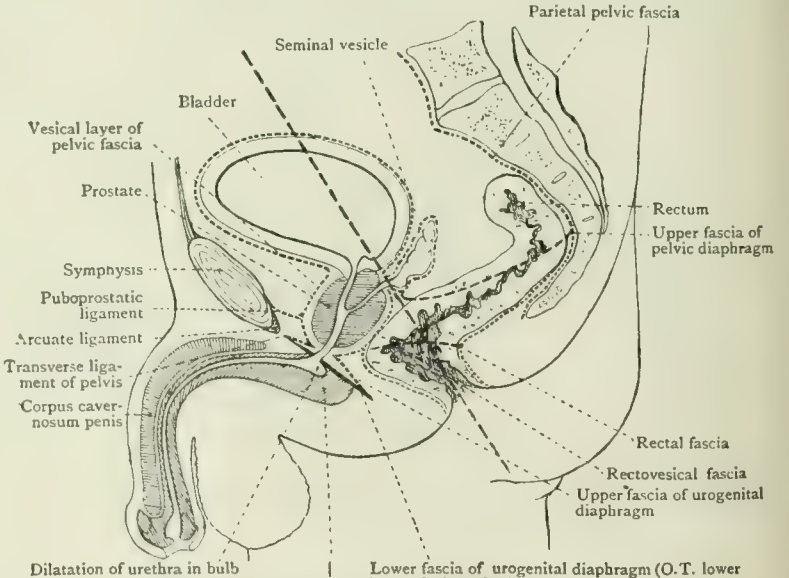

Fig. 2364.—Diagram of the Pelvic Fascia as seen in a Sagittal Section of the Pelvis. This fascia is represented by the broken lines. (After Cunningham.)

The superficial fascia of the perineum consists of two quite distinct portions, one behind the transversus perinei superficialis, the other in front of that muscle. The posterior portion is made up of fatty tissue that fills up the ischiorectal fossa and forms cushions

over the tuberosities of the ischium where it is closely adherent to the deep fascia.

The anterior portion has a superficial layer of areolar adipose tissue continuous with that just mentioned and with the similar layer of the thigh, and a deeper layer condensed into a resistant membrane attached behind the transversus perinei superficialis

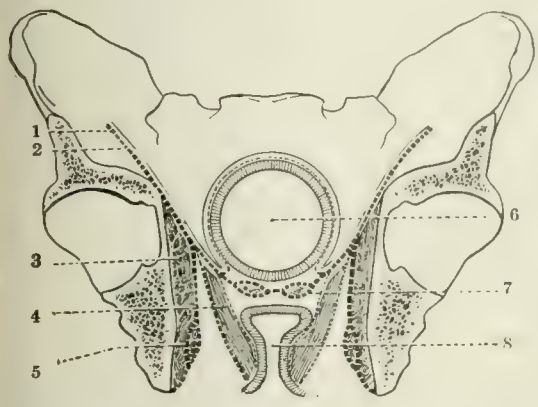

Fig. 2365.—Diagram of the Endopelvic Fascia. The pelvis is divided in a coronal plane and the pelvic fascia is represented by the broken lines. 1. Fascia iliaca; 2, peritoneum; 3, obturator internus; 4, levator ani clothed on medial side by rectal fascia and on outer side by lower fascia of pelvic diaphragm; 5, Alcock's canal containing pudendal vessels and nerve; 6, bladder,; rectovesical fascia; 8, anal canal. (After Cunningham.)

to the deeper layer of the urogenital diaphragm and laterally to the pubic arch, continuous in front with the superficial fascia of the anterior abdominal wall.

The application of this arrangement to the retention of fluids may be readily seen. The pelvic fascia completely encloses the cavity. A pelvic abscess above it will be prevented from pointing externally; below

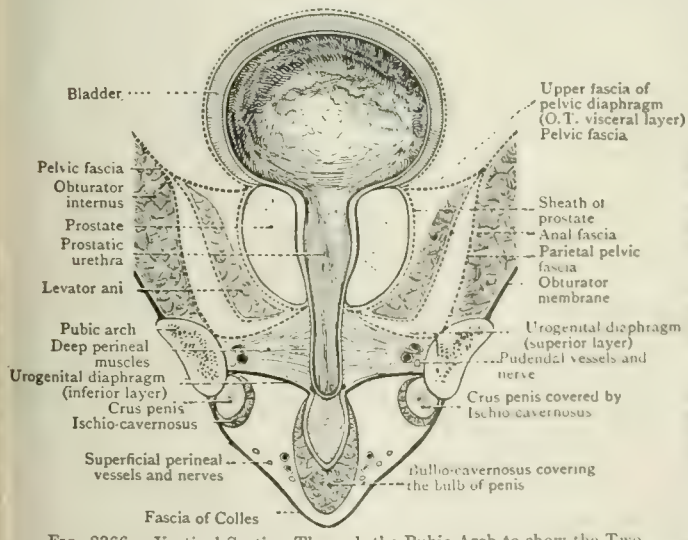

Fig. 2366.—Vertical Section Through the Pubic Arch to show the Two Perineal Compartments. (Schematic, after Cunningham.)

it must come out upon the perineum, either in front, which is rarer, or behind. Any wound of the pelvic fascia (as in operations on the urethra or bladder) is dangerous, because it opens up the subperitoneal tissue.

The attachment of superficial fascia to the urogenital diaphragm prevents effusions from passing outward upon the thighs, but allows them to pass upward upon the abdomen.

In accordance with the general rule that the development of these structures is determined by mechanical activity, the fascia of the limbs is ordinarily thicker and stronger than that of the trunk.

Thorax.—The superficial fascia over the front of the thorax is thick and fat[illegible] muscular fibers from the platysma [illegible] over the clavicle and elastic fibers that pass from the deep surface of the skin between the lobes of the mammary gland.

The deep fascia consists mainly of the perimysium of the pectoralis major (pectoral fascia) attached to the sternum and clavicle and continuous with the axillary and abdominal fascia. The perimysium of the deeper surface of this muscle is connected by loose, areolar tissue with a strong sheet, the costo-clavicular fascia, that passes from the first rib, the clavicle and the coracoid process over the interval between the clavicle and the pectoralis minor. It splits to enclose the subclavius and the pectoralis minor and is then continued downward to join the axillary fascia, assisting to hold it in a vaulted condition and hence called by Gerdy the suspensory ligament of the axilla (fascia coracoaxillaris, Eisler; not in BNA). The denser band of this fascia that passes from the first rib to the coracoid process is sometimes distinguished as the costocoracoid ligament. The coracoclavicular fascia is pierced by the cephalic vein, the coracoacromial artery and vein and the lateral anterior thoracic nerve. The oval opening through which these structures pass has been called by Eisler the fossa ovalis infraclavicularis (not in BNA).

Axilla.—The axillary fascia is that continuation of the pectoral fascia that extends between the folds of the axilla, covering over the serratus anterior on the inner side and blending with the fascia covering the arm and that over the latissimus dorsi. Elastic fibers accommodate it to the various movements of the arm. Over the central portion of the axillary fossa it is quite thin, and affords passage to a number of small vessels and the branches of the intercostobrachial nerve. It has been named by Eisler the lamina cribrosa axillaris (not in BNA). When this thin layer is removed there appears an oval opening of considerable size exposing the axillary vessels and nerves. This is often bordered by [illegible] marked bands on the thoracic and brachial aspects. Langer considered these as constant structures and named them respectively the arcus axillaris (Achselbogen) and the arcus brachialis (Armbogen). They are now generally thought to be artificially produced, though muscle fibers are [illegible] found in these situations.

Shoulder.—The fascia of the shoulder is a continuation of that of the breast and back, quite thick and strong over the [illegible] infraspinatus, where it sends septa between the muscular fasciculi, thin and delicate over the teres minor and subscapularis.

Arm.—As the muscles of the upper arm are comparatively simple, being composed of two groups, the flexors and extensors, with the coracobrachialis as a possible third member, the brachial fascia is a simple sheath, attached above, through the deltoid and pectoral fascia, to the clavicle, acromion, and spine of the scapula, divided into two compartments by strong intermuscular septa, and attached below to the epicondyles and the olecranon and becoming continuous with the fascia of the forearm. It is made tense by [illegible]

the pectoralis major and deltoid, and is stronger on its posterior aspect.

At the upper part of the arm separation of the two groups of muscles is effected on the medial side by vessels and nerves emanating from the axilla, but below the lesser tubercle of the humerus a strong septum commences which, blending above with the tendon of the coracobrachialis, may be considered as a continuation of that structure. It is attached below to the epicondylar ridge and the epicondyle. In front of it lie the brachial vessels and the median nerve, and just below the middle of the arm the investing sheet is pierced to allow the basilic vein to join the brachial. This opening, called the hiatus semilunaris by Henle and the hiatus basilaris by Rauber-Kopsch, is not noted in the BNA. The medial cutaneous nerve of the forearm, as well as some lymphatic vessels, also pass through this opening. The medial brachial cutaneous nerve pierces the brachial fascia farther up. The brachialis muscle and the pronator teres lie in front of the medial septum and the medial head of the triceps behind. The ulnar nerve and the superior ulnar collateral artery are at first in front of the septum, but, just below the insertion of the coracobrachialis, they penetrate it and lie behind it. Tillaux cautions the operator wishing to tie the brachial artery against getting into the posterior compartment and mistaking the superior ulnar collateral with its companion nerve for the brachial with the median nerve.

The lateral intermuscular septum extends from the greater tubercle of the humerus and the insertion of the deltoid along the lateral supracondylar ridge to the lateral epicondyle. It is not as strong as the median septum, but affords insertion to the fibers of the triceps behind, the brachialis, brachioradialis and extensor carpi radialis longus in front. The radial nerve and the profunda artery of the arm penetrate it from behind forward a short distance above the epicondyle.

To accommodate itself to the varying form of the biceps brachii the fascia is not closely adherent to the muscle in front, and is provided with elastic fibers. It is pierced by cutaneous nerves and vessels as follows:—by the lateral brachial cutaneous nerve from

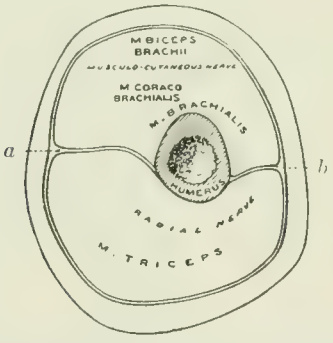

Fig. 2367.—Diagram showing how the Arm is Divided by the Intermuscular Septa and Bone into an Anterior and a Posterior Compartment. *a*, Medial and *b*, lateral intermuscular septum. (After Turner.)

the axillary, about the middle of the posterior border of the deltoid; by the posterior brachial cutaneous and the dorsal antibrachial cutaneous from the radial, near the upper end of the lateral intermuscular septum; by the lateral antibrachial cutaneous in the cubital fossa near the lateral edge of the biceps tendon. The cephalic vein ascends along the lateral septum outside the investing fascia to the shoulder, where it pierces the pectoral fascia in the deltopectoral groove. In the cubital fossa there is a foramen of somewhat variable situation by which the deep and superficial veins of the arm communicate.

Forearm.—The fascia of the lower arm (fascia antibrachii) is a dense investing sheet firmly united to the muscles and reinforced by fibers which descend obliquely from the medial epicondyle, from the tendon of the biceps (lacertus fibrosus) and from the tendon of the triceps over the anconeus (lacertus fibrosus musculi tricipitis, Fränkel, not in BNA). These last serve as tensors of the fascia. There are also transverse fibers that extend from the posterior border of the ulna in both directions and near the wrist these are condensed to form retaining bands, the so-called annular ligaments (transverse carpal, volar carpal, and dorsal carpal ligaments). From this strong

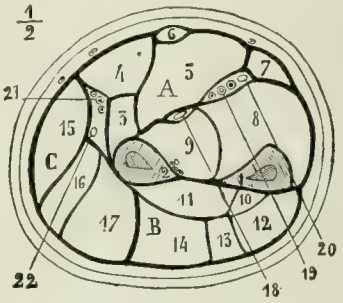

Fig. 2368.—Fascial Compartments of the Forearm.

investment well-marked septa pass between the muscles serving for the insertion of muscular fibers and ensheathing compartments that hold the individual muscles in place. In the proximal part of the arm these compartments are arranged in three groups as shown in Fig. 2368, A, B, C; distally there are added to these the extensor indicis and the extensor pollicis brevis. The supinator, and the pronator quadratus have special compartments of their own and the compartments of the palmaris longus and the flexor carpi ulnaris are especially well marked. The necessity for independent movement of the individual muscles causes the spaces between the different compartments to be filled with rather loose connective tissue which favors the burrowing of inflammatory products.

The radial vessels and the superficial branch of the radial nerve pass down between the brachioradialis and the contiguous muscles; the ulnar vessels and nerve and the median nerve lie between the superficial and deep flexors.

Wrist.—At the wrist the fascia is thickened by the transverse retaining bands already mentioned. On the flexor surface the deeper one of these, the transverse carpal ligament, bridges over the carpal groove, thus producing the so-called carpal canal in which the flexor tendons and the median nerve pass to the hand; superficially the volar carpal ligament stretches from the edges of the radius and ulna over the flexor tendons before they enter the canal. The ulnar vessels and nerve seek a special passage on the radial side of the pisiform bone which has been called the ulnar carpal canal (Rauber-Kopsch, not in BNA).

On the dorsal surface of the wrist a strong fibrous band, the dorsal carpal ligament, extends, attached to the styloid process of the ulna and to the ridges upon the distal end of the radius. There are thus formed the following distinct compartments for the passage of the various tendons:

1. Abductor pollicis and extensor pollicis brevis.
2. Extensores carpi radiales longus and brevis.
3. Extensor pollicis longus.
4. Extensores digitorum communis and indicis proprius.
5. Extensor digiti quinti proprius.
6. Extensor carpi ulnaris.

The sheaths which line these compartments extend

down into the hand. Their arrangement is shown in the article *Bursæ*.

Hand.—The palmar fascia is apparently a continuation of the tendon of the palmaris longus, and in its central portion is a thick, dense, triangular expansion that covers the hollow of the palm, protecting from injury the subjacent structures and firmly united to the skin which here is never thrown into folds. It varies much in density according to the occupation and habits of the subject. Distally it divides into four slips which pass to the four medial digits, blending with the sheaths of the flexor tendons. The palmaris longus is in some mammals a powerful additional flexor, and this fascia probably represents a degraded condition of the primitive type. It is, however, present when that muscle is absent, extending up the arm as a fibrous cord, apparently a still more regressive stage. There may be a band passing from it to the thumb. The lateral and medial portions of the fascia are thin and delicate, covering the muscles of the thenar and hypothenar eminences. At the webs of the fingers the fascia becomes thickened again with transverse fibers, forming the superficial transverse ligament, called by Braune the ligamentum natatorium or swimming ligament. From the deep surface of the palmar fascia two thin septa extend to a subjacent layer covering over the interossei muscles, thus dividing the palm into three compartments: a central one which contains the flexor tendons and the lumbricales; a median one containing the muscles of the hypothenar eminence; and a lateral one containing those of the thenar eminence.

Thigh.—As already mentioned, the iliac fascia clothes the iliopsoas muscle and is continuous under the inguinal ligament with the fascia covering the pectineus. From the iliopectineal eminence a septum divides the space under the ligament into two compartments; a lateral one, the lacuna musculorum, containing the iliopsoas muscle and the femoral nerve; and a medial one, the lacuna vasorum, containing the femoral artery, the femoral vein and some lymphatics, arranged in that order from the lateral to the

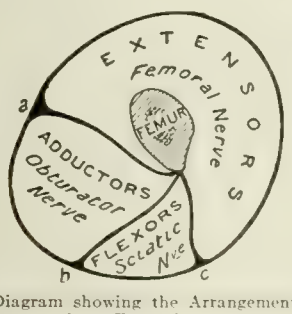

Fig. 2369.—Diagram showing the Arrangement of the Three Intermuscular Septa and the Three Osteofascial Compartments of the Thigh. *a*, Medial, *b*, posterior, *c*, lateral intermuscular septum. (After Turner.)

medial side. This septum is sometimes called the iliopectineal ligament (not in the BNA). When the psoas minor is present it appears to be an expansion from the tendon of that muscle, otherwise it is merely a thin strip of the iliac fascia. The vessels are ensheathed (vagina vasorum femoralium) by prolongations of the transversalis fascia in front and the fascia covering the pectineus behind. This latter, a prolongation of the iliac fascia, is generally known as the iliopectineal fascia. The funnel-shaped interval between the psoas and the pectineus within which the vessels descend is known as the iliopectineal fossa. It is bounded above by the inguinal ligament and extends below to where the great vessels are given off. Between the vessels and the lacunar ligament is a space, the femoral ring, closed in by subperitoneal fat (the septum femorale) [illegible] through which a femoral hernia may protrude.

From the medial edge of the [illegible] investing fascia of the thigh [illegible] tent the fascia lata, is continued over the [illegible] fossa and the vessels it contains, attached [illegible] inguinal and lacunar ligaments. It is over this that the great saphenous vein, carrying most of the blood from the surface of the limb, empties [illegible] vein. This causes a depression on the [illegible] the fossa ovalis, the lateral edge of which, being sharply curved, is known as the falciform [illegible] edge, not so well marked, dips under the great saphenous vein and becomes continuous with the iliopectineal fascia. The two extremities of the edge thus superposed are called the superior and inferior cornua. The circumference of the [illegible] mentioned as if it were an opening in the fascia lata, and as such styled the external femoral ring (not in BNA), but the depression is in reality covered by a thin membrane which, as it is pierced for the transmission of numerous small vessels as well as for the great saphenous vein, is called the cribriform fascia. The passage which may be forced by a hernia along the vessels from the internal to the external ring is termed the femoral canal.

The fascia lata invests the entire region of the thigh, attached above to the sacrum, the crest of the ilium, the inguinal ligament, and the rami of the pubis and of the ischium; and below to the prominences about the knee. It varies in thickness in different parts, being strongest in front and laterally, weaker behind and medially, and thickened below by transverse fibers from the vasti muscles. The tensor fasciæ latæ and a considerable portion of the glutæus maximus act as tensors of this fascia, all being inserted upon a thickened tract of the fascia at the lateral portion of the thigh which extends from the crest of the ilium above to the tuberosity of the tibia below and is known as the iliotibial band (tractus iliotibialis). This band is generally considered as the homologue of a tendon that has become united with the fascia. The tensor being supplied by the superior gluteal nerve, it has been proposed to call this blended muscle the gluteus anterior.

Septa pass from the fascia lata between the three great groups of muscles of the thigh, the extensors, flexors and adductors. The lateral and medial ones are well marked, the posterior one, between the adductors and the flexors, somewhat less so, therefore not noted in the list of the BNA. In the distal part of its course the medial septum is closely blended with the tendons of insertion of the adductor muscles, and about the middle of the thigh it is obscured by transverse fibers that pass from the vastus medialis to the adductor longus and adductor magnus, roofing over a passage for the femoral vessels and the saphenous nerve called the adductor canal.

Behind the knee the fascia lata is continuous with the popliteal fascia which roofs over the popliteal space. It is strengthened here by transverse fibers, derived from the tendons of the hamstring muscles which act as tensors and is perforated by the small saphenous vein. Laterally it forms the collateral patellar ligaments, attached to the patella and holding it in place. It is of sufficient strength to offer considerable resistance to an aneurysm or to the formation of abscesses.

Leg.—The deep fascia of the [illegible] completely invests the limb, blending with the periosteum on the medial surface of the tibia. Above it is continuous with the fascia [illegible] fascia. Septa pass from [illegible] making a compartment for the peroneal muscles. There is also a transverse septum separating the superficial and the deep muscles of the calf. About the ankle this fascia is thickened to form retaining

bands (formerly called annular ligaments) for the tendons that pass to the foot. The proximal thickening (ligamentum transversum cruris), is a strip some two or three finger-breadths wide passing from tibia to fibula above the malleoli. It holds down the tendons of the extensors and of the tibialis anterior, the latter only having a synovial sheath at that level. Distal to this is the cruciate ligament (ligamentum cruciatum cruris), usually Y-shaped, the stem arising from the dorsal surface of the calcaneus and then looping around the tendons of the peroneus tertius and the extensor digitorum longus. This peculiar arrangement caused Retzius to name it the ligamentum fundiforme or sling-like ligament. From it the branches of the Y diverge, the proximal branch

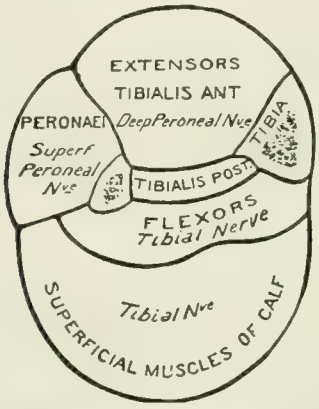

Fig. 2370.—Diagrammatic Representation of the Fascia of the Leg. The fascia of the tibialis posterior is more a muscular aponeurosis than a true fascial septum, but it is convenient for descriptive purposes to regard it as one of the partitions. (Cunningham.)

passing over the tendons of the extensor hallucis longus and the accompanying vessels and nerves, but enclosing the tendon of the tibialis anterior, becoming finally attached to the tibial malleolus; the distal branch passing over all these structures to become attached to the border of the deep plantar fascia. The stem of the Y may split into two bands, giving the whole ligament the shape of an X, justifying the name of the cruciate ligament. On the medial side of the ankle the structures passing down into the foot are retained in place by the laciniate ligament, extending from the tibial malleolus to the margin of the calcaneus. Under this there are four compartments, in the following order from the medial side: 1, for the tendon of the tibialis posterior; 2, for the tendon of the flexor digitorum longus; 3, for the posterior tibial vessels and the tibial nerve; 4, for the tendon of the flexor hallucis longus. The tendons are here surrounded by synovial sheaths. A somewhat similar arrangement is made on the lateral side of the ankle by fibrous bands, the peroneal retinacula, which bind down the synovial sheaths of the peroneus longus and brevis. The fibers of the superior retinaculum run from the fibular malleolus to the lateral surface of the calcaneus, those of the inferior retinaculum are continuous in front with the stem of the cruciate ligament, and behind are att ached to the lateral surface of the calcaneus.

Foot.—Upon the dorsum of the foot the fascia is thin, covering over the extensor tendons, on the sole it is very thick and strong, having longitudinal fibers attached behind to the tuberosity of the calcaneus and extending forward to be inserted by five slips into the skin and flexor tendons of the several toes, which slips are united by indistinct transverse fibers. The fascia assists in preserving the arch of the foot (see article *Foot*). Lateral and medial portions cover the plantar muscles on either side. Like the palmar aponeurosis it is thought to be the vestige of an additional flexor muscle which would be represented in the calf by the plantaris that in apes and lemurs reaches the sole. Intermuscular septa pass from this fascia, dividing the muscles of the soles into three groups, the middle one of which is the flexor brevis.

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Fasciola.—A genus of flukes, *Fasciolidæ*, in which the body is broad and leaf-like, the anterior end is conical and contains the mouth. The ventral sucker is near the mouth; cuticle covered with spines. *F. hepatica* is found all over the world. It is found as an adult in sheep, goats, cattle, horses, man, and other animals; usually in the bile ducts of the liver, but often in other situations. The larva uses the pond snail as an intermediate host, and then becomes encysted on vegetation which may be eaten by the final host. See *Trematoda*. A. S. P.

Fascioletta.—A genus of flukes, *Fasciolidæ*, in which the body is small, elongate, broader anteriorly than posteriorly, without cuticular spines. *F. ilocana* has been found in the intestine of a Filipino. See *Trematoda*. A. S. P.

Fasciolidæ.—A family of digenetic flukes which are hermaphrodite and possess oral and ventral suckers; the excretory pore is at the posterior end. Important genera are: *Fasciola*, *Fascioletta*, *Agamodistomum*, *Fasciolopsis*, *Opisthorchis*, *Clonorchis*, *Metorchis*, *Paragonimus*, *Heterophyes*, and *Dicrocœlium*—all found in man. These worms are parasitic in the liver, intestine, and other organs. See *Trematoda*. A. S. P.

Fasciolopsis.—A genus of flukes, *Fasciolidæ*, in which the head is conical, without cuticular scales; the acetabulum is prolonged posteriorly into a pouch; the intestinal ceca are unbranched. These worms are two inches or more in length. Two species have been described from the intestines of men in China and India. See *Trematoda*. A. S. P.

Fasting.—See *Starvation*.

Fatigue.—We may define fatigue so far as it relates to man and his congeners, the most highly evolved brutes, as a functional loss of irritability of the nervous system arising from overuse. Formerly, in the physiological days of the isolated gastrocnemius ranæ, it was customary to speak also of a muscle fatigue, and Angelo Mosso made very famous contributions to technical physiology of the loss of irritability in this direction. We physiologists are now giving up, slowly enough, to be sure, such study of protoplasm under absurdly abnormal conditions, and are at last be-

ginning, at least, to wrestle with the harder, but realer, problems of actual, that is living, normal protoplasm as part of a breathing, metabolizing unity of life. We begin to see now, in short, that there is not better reason for studying a frog's muscle cut off from its circulation, optimum temperature, oxygen, etc., than for using it as physiologic (*i.e.* "normal") material after having been dried or soaked in a poisonous solution. Living animalcules, for example, the crustacean Daphnia, transparent and complex, living integrations are taking the place of isolated tissues as physiologic "material." (See the present writer's article "A Laboratory Course in Physiology based on Daphnia and Other Animalcules" in "*Biologische Centralblatt*, Erlangen, Bd. xxxii., 5, May 20, 1912; *Boston Med. and Surg. Jour.*, clxvii., 5, August 1, 1912). A chief reason in another direction why we tend to confine considerations of fatigue to the nervous system lies in the now well appreciated fact that a normally nourished muscle supplied with normal nerve supply shows little sign of fatigue, in the proper sense of the term, short of actual material wear and tear such as every machine, even one made of steel, is universally subject to; but we should call this neither fatigue nor even exhaustion for it is properly injury due to overuse, and injury is not fatigue any more than paralysis is inhibition. One of the functions of the nerve cells is to act as "governors" and safety-valves of the organism, in part mechanically, and in part by way of consciousness. For this reason in the actual animal living about his business, fatigue is always nerve fatigue—although, to be sure, invidious separation of tissues is to be avoided in any physiologic or psychologic discussion, for the actual individual is always, more or less, a perfect integration.

Fatigue, then, is always abnormal in so far as this attitude is not incompatible with its biologically teleologic function of protecting the organism and its parts from overexertion and from unhygienic conditions. It is always a consequence of *abuse* and not of use alone. Fatigue is then an abnormal state.

Few facts at the present time are more pregnant with meaning and value for the public at large than that *fatigue is always an abnormal condition*, to be avoided in general in the same way as is pain and largely for the same reasons; both are indicators of impending or actually contracted harm. In emphasizing this essential consideration it apparently is necessary to suggest that such a rule must be administered with the usual modicum of common sense, for otherwise, as sundry old-fashioned educators have protested (and the same conditions apply in therapeutics), the effect undoubtedly might sometimes be to make mollycoddles of the children and of the patients. There is clearly no hard and fast rule as to where the feeling of fatigue begins in every individual. Hence a child or a patient is by no means to avoid all feeling of fatigue but is to use his will-push for the acquirement of reasonable and always beneficial habits of *physiological* endurance. As long as it is physiologic and not pathologic, it is of course not properly subject to the limitations of fatigue at all.

Not enough distinction has been shown between fatigue and exhaustion; they belong in the same logical category, but they are very different conditions. We can illustrate this difference in general by the following apt comparison: Take a society woman who goes to an afternoon tea and there does a great deal of talking as well as the proverbial "giggle, gabble, gobble, and git," of O. W. Holmes, or she goes to a fair or to a large dog show and in the course of her afternoon she becomes very "weary"; that is fatigue. Now compare this condition of fatigue with the condition of neurasthenia in which the person has gone on with that sort of thing for months, that is afternoon teas, fairs, opera, and dog shows, and with it all has not had enough life and not enough sleep and [illegible] a condition of exhaustion. [illegible] exhaustion of the food supply to the nerve centers, a loss of metabolic material in the nerve cells and fatigue means a temporary lowering of [illegible] which is overcome by a good night's sleep or by one or two good meals.

We may discuss one phase of the theory of fatigue, then, under three heads: first, the feeling of fatigue, (*a*) general fatigue and (*b*) general [illegible] neural or organic fatigue and exhaustion; third, muscular fatigue.

The feeling of fatigue is total weariness, and an example of such would be the condition of fatigue resulting from going to a great exposition where there are things from all over the world to interest one and to take up one's eager attention and where the person goes day after day; you have when you get through such a period of sight-seeing a condition in which you are tired in body, mind, and soul. There are three factors that enter into such a condition: (1) A universal fatigue of the gray nervous matter which we can call general gray-matter fatigue, especially fatigue of the reflex spinal centers and the sensory brain centers. We can readily see how such a condition comes about when one is experiencing all sorts of reflex attention to every kind of a thing whereby a great many reflex and sensory centers are involved. (2) A general mild muscular fatigue is a part of the condition of weariness; the glycogen for example is more or less gone from the muscles and from the liver. In the circulation and affecting the nerve cells, on the other hand, there is more or less lactic acid and carbon dioxide, as well as in the muscles, together with potassium acid phosphate, these being the ordinary "fatigue products" of the action system. According to Weichardt, there is also present a true toxin which he calls kenotoxin. All of these substances pass more or less into the circulation and the muscles. Their presence serves to depress to some extent the brain centers. (3) A third factor of general weariness is that the stomach and the upper intestine, the duodenum and the upper end of the jejunum, are more or less empty, and, therefore, the constant blood stream is slightly depleted of its nutriment and fine metabolic substances.

General fatigue is much more noticeable in city life than elsewhere (other factors, however, help to make country life fatiguing), and were it not for coffee, tea, tobacco, alcohol, or cocoa, this fact would be much more commonly evident, for there are very few adults who do not use some one of these substances. The average individual living in the rush of an active city life never realizes that he is tired because he almost invariably takes some form of stimulant, which is, physiologically speaking, an abnormal thing. We are not aware of general fatigue because the nervous system is constantly being ordinarily stimulated by things which are taken for the express purpose of preventing the feeling of fatigue. These things are not concerned with the physiological nutrition of the nerve centers and do not serve to prevent their wear and tear. Therefore this is a condition which leads to nervous prostration and sometimes to untimely death. The mind and the body both are involved in this general sense of weariness, in this "general fatigue" not the fatigue caused by [illegible] as a Marathon race, or a severe mountain climb, oberve, but a *general* condition of fatigue as the result of the combination of active city life proper and the strain attendant upon that life, in which the nerve cells, and especially those of the cortex cerebri, bear the brunt. Under the ordinary conditions in which the person has a good [illegible] this general condition of fatigue is [illegible] by the eating of food of especially quickly digestible material; the eating of liquid foods promptly relieves the [illegible]

of this fatigue because it feeds the nerve cells within three minutes from the time that it is taken into the body. The nerve cells get immediate nutriment after drinking a cup of strong hot bouillon or of malted milk.

The second kind of fatigue is pure nerve fatigue. This is neural fatigue and exhaustion and it is an organic sort of fatigue, for it is the nerve cells that are concerned. We can arrange a nerve-muscle preparation so that we can stimulate it for hours with a strong induced electric current and at the end of that stimulation the nerve will conduct to the muscle just as well as it did before. Although the nerve fibers do not fatigue easily, they cease their action after a period of from three to five hours when they are deprived of oxygen. (See Verworn's discussion, below.)

Professor Hodge showed that changes occur in the the nerve cells of birds, etc., when greatly fatigued by excessive or by unrested activity. It has been more recently shown that these changes in the nerve cells are due to a loss of chromatin and of the chromatin masses. Hertwig pointed out the interdependence of the nucleus and the cytoplasm as regards their respective sizes in fatigue. Muscular activity such as that produced by a dog in a treadmill causes in the Purkinje cells, large branched cells of the cerebellar cortex, the following changes: In the first place, a steady increase in the chromatin (the Nissl bodies) in the cytoplasm, and of the tigroid substances in the nuclei; thus there is an increase in the size of the whole cell, a fact which misled observers for some time, for the first step *toward* fatigue is an increase in the metabolic power and in the nutritional metabolism of the nerve cells. The increase of chromatin in the first place becomes marked so that the nerve cells of Purkinje in the cerebellar cortex take on more than their normal supply of nutriment; here it is that the normal limit of neuromuscular action comes in. The nervous system supplies itself with metabolic material for activity, and, if the activity does not go beyond that stage, it is physiologically normal, for this is the anabolic phase by which the nerve cells build up and store material.

If the activity continues beyond this stage, there comes on the katabolic phase, in which the waste begins to overcome the supply, the anabolic phase, and this takes place in the following way: The first thing is the passage of the chromatin material out from the nucleus into the cytoplasm. Second is the passage of nutrient material from the cytoplasm outward into the lymph spaces. The third stage is that of edema of the nucleus in which it swells up, for owing to some osmotic derangement the nucleus absorbs liquid. Fourth, there occurs an edema of the cytoplasm. It is owing to this edema of the nerve cell at this stage that it looks normal, but there is a reversal of the proportion in the relative sizes of the nucleus and the cytoplasm. The fifth stage in this process is when the chromatin osmoses out from the cytoplasm. The sixth stage is when it osmoses out from the nucleus; both neucleus and cytoplasm are now larger than normal, and this is the onset of exhaustion. That occurs when the chromatin, by repeated interchange, has osmosed out from the cell; the cell is then in a completely exhausted condition. The seventh stage is when the basic protein or chromatin of the nucleus has entirely gone.

There are two phases, then, the anabolic phase, which is accompanied by a steady increase in the amount of nutriment in the nucleus and the cytoplasm. This is the normal limit of activity. Second, there is the catabolic phase, a decrease in the chromatin masses in the nerve cell. Chromatin, in general, is understood to be the nutrient material of the nerve cells.

These seven stages according to D. H. Dolley's account leave the nerve cells in a condition of exhaustion such as we would have with a very bad case of neurasthenia, and he points out that this is precisely like the phenomena found in cases of anemia. The conditions observed in bad anemia are, Dolley thinks, like the conditions observed in surgical shock, so that anemia and surgical shock are practically the same in so far as the nerves are concerned: extreme fatigue going on to a condition of exhaustion. The increase in the size of the nerve cell at first is a preparation for the increased activity, and, secondly, the increase is due to an abnormal swelling up with lymph rather than being due to a strong basis of nutrient material.

Another factor in this nerve-cell fatigue is that of hormones. In this connection one hormone especially is talked about lately and that is the secretion of the hyroid gland known as iodothyrin. The amount of available and efficient nervous energy in exophthalmic goiter is very much decreased and thereby the coordination of the muscles is more or less imperfect. The speed of the muscle actions and the accuracy of the control are lessened. These are conditions due to a disturbance of the nutrition of the nerve cells from excessive amounts of iodothyrin in the circulation and represent fundamentally some defect in the nutrition of the nerve cells.

Another step in our real, that is physiological, knowledge of fatigue has been usefully suggested by the versatile William McDougall, reader in philosophy at Oxford. He points out the importance in the theory of fatigue of the reservoir idea frequently employed in the past in neurological discussions. This tentative but highly important notion is, in short, that the afferent, sensory side of the nervous system is, properly speaking, a reservoir of nerve energy and that every sensory neuron contributes continually to this nerve supply of energy. The afferent side of the nervous system receives, holds, maintains, and stores energy. McDougall points out (*Brain*, xxxii., 1909, 257–268) further, that fatigue is a balance between the supply and the extent of expense of nerve energy, that is between the expenditure and the income of nervous energy. The synapses from this point of view (following the viewpoints of both Sherrington and Schäfer) are gates by which the central nerve energy escapes. When you are biologically interested in that which you are doing, all of the special sources of muscular and especially nervous energy and strength are more open, and the neural reservoir may be exhausted. Take, for example, the severe illness of someone dependent upon you when you would be obliged to sit up all night and when you would get but very little sleep for weeks. Such a siege is enough for the exhaustion of nervous strength. Under conditions of such interest you do not notice the fatigue, and you overcome it when you are thus excited or very much interested; as a result you do not realize that you are becoming very tired. On the other hand, in like manner, when you are not interested but are in a condition of boredom and ennui, the balance goes quickly to the side of fatigue and there is consequently then also a great loss of mental energy; and you feel tired.

Fatigue, then, is a protective factor of the organism, and, if we are concerned in something that is a matter of interest to us, it has much to do with keeping up the plane of efficiency by maintaining the resistance at the gates or the synapses. McDougall has certainly mixed up the feeling of fatigue and physiological fatigue to some extent. None the less, the suggestion that fatigue involves both the "reservoir" and the "synapses" (two hypothetical but useful concepts) is of no little value in the doctrine of fatigue.

The third kind of fatigue is "muscular" fatigue pure and simple, or as pure and simple as it is reasonable to talk about it. In this discussion I shall consider muscular fatigue as little as possible because in the living individual patient or school child muscle

fatigue has certainly little part, the nerve cells acting as most efficient safety-valves for the muscles and neurones and therefore lessening or stopping action before the muscles proper can be injured or even badly fatigued.

Angelo Mosso, the great classic original investigator along the lines of muscular fatigue, is an authority upon this subject, although much of his work is for therapeutic and pedagogic purposes now seen to be misleading. Mosso's ergograph by which the fatigue of the index-finger is studied is to be found in every physiological laboratory in the world; they are, however, now using a spring (S. J. Franz) instead of a weight, and you get, therefore, isometric contraction instead of isotonic contraction. Most of this sort of thing has been done and discussed *ad nauseam* and much of it has been shown to be misleading because the conditions as they were studied were too arbitrary and too artificial and many of the researches were made on isolated muscles and nerves. You find out but little as to the actual living conditions in the fluid body when you take out a single muscle and study its fatigue. Moreover, it is almost as bad to study a "single muscle" in the body (*e.g.* flexor indicis) as to take out entirely the frog's gastrocnemius muscle and, while thus isolated, to study it in order to learn of "the actual conditions."

Save as pure physiology, therefore, muscular fatigue has little meaning, since it rarely occurs in the actual individual or if it does so, from gross muscular exertion, it impels to the soundest possible sleep or to waking rest (more quickly restful to the muscles than sleep, of however little account toward relieving the fatigue of the neurones).

The commonest causes of actual fatigue among actual patients cannot properly be omitted from a discussion, however brief, of fatigue, since they are part and parcel of the fatigue itself and explain its conditions to a considerable extent.

Pre-eminently notorious among the common modes of nerve extravagance and waste is *worry*. This is the sheerest wastefulness in all our lives—expenditure with nothing and worse than nothing in return. Worry, when needless, is the very stock-gambling of extravagance in vital forces without possibility of a "bull market" or a "bear market" to recoup in—dice-throwing, with the dice loaded always against you. In the terms of our discussion, every hour spent in worrying about some evil, whether real or imaginary, is a large and wholly needless check drawn on your bank balance of bodily and mental strength. If one borrow trouble the rate of interest that one has to pay is rank usury.

We may define worry as *the habit of wasting the soul and the body on evils that have not come.* Many of its victims might properly define it in the same terms that General Sherman used in regard to war—brief, but at once philosophic and expressive. James Russell Lowell never wrote anything more true than his statement that "the misfortunes hardest to bear are those that never come," for the human imagination running riot is very apt to make things seem worse than kindly Nature often allows them actually to be.

Worry is described by the physiologists as essentially a form of more or less chronic fear—fear that something evil is going to happen. Fear, of course, does not well become the strong man or woman; although, as everyone who is grown up knows too well, some worries cannot be avoided in this troubled life (fear of the illness and death of friends, for example). These must be met as is fitting to the brave.

Since the valuable physiological work of Austin and Sloan on the nerve cells of rabbits, we know the actual effects which fear produces in the nervous systems of animals, and we know that the effect is very serious and widespread in the body. Worry must produce this same effect, and often to a greater degree even than a period of terror, which of course [illegible] but a short time, so exhausting it [illegible]

Such facts [illegible] more preventive of extravagance [illegible] sort of mere logic would be. [illegible] argument of course reads: If [illegible] can be prevented or cured [illegible] than suffer so; if it cannot be cured or prevented, why waste energy and time suffering [illegible] Excellent logic, certainly, but woefully incompetent, as most of us well know, to restore the wasting brain-cells, or to abolish unrested [illegible] The reason why so few worriers adopt the [illegible] expressed advice not to worry is that worry has the emotional basis just now suggested, that it is a *feeling*, with a tremendous motive power behind and beneath it, hard to be controlled. We need not pause to describe in detail the physical and mental effects and conditions of fear and worry; suffice it to say that its depressing influence arises and is felt in well-nigh every portion of the body—bowels, stomach, heart, blood-vessels, lungs, brain, muscles, and nerves—and therefore unfits its victim for every free and useful act.

The motive power of much of our human activity is emotion or feeling, and those emotional states that depress the nerve centers tend to paralyze action, lessening at the same time our desire to do things, and our power of doing them well when we try. Here it is that happiness comes into the matter. Multitudes of men and women learn sooner or later that not always, by any means, as we have often heard, is the race to the swift, or the battle to the strong; often, very often indeed, one inclines to think that both go to the *happy*, lords of the world.

Other modes of waste in nerve values when combined are of much importance, although together even probably less harmful to life efficiency than worry. One of these other ways of extravagance is the habit of excessive emotion pleasant or [illegible], for even an excess of joy will tire, and that unduly, the nervous centers. This circumstance, it is likely, depends primarily on the very large proportion of the nerves and muscles that are strongly active in any well-defined emotion or feeling, and this is so whether gross muscular movements be discernible or not. Muscle constitutes nearly half the mass of the body, and practically all of it is set in some degree of activity as a factor of joy or grief or love or fear, and with it most or even all of the nerves are working more or less actively. The emotional aspect of the mind is a most important phase of it, and its high tension oftentimes makes rapid inroads, far more rapid than is appreciated at the time, or our bank account of nerve energy, on the nervous "reservoir" as McDougall and Claparède call it. "A short life and an over-emotional one" would be a motto far less expedient for most men and women than a long life and an [illegible] the nerve cells wear out!

Every keen observer of human behavior distinguishes at a glance the disorderly person from the orderly, but not all of them realize that order, besides being attractive (when not overdone), is eminently economical of nerve energy. This principle [illegible] and to mental orderliness. Take, for example, the routine formulæ required of telephone operators and see the immense saving, not only of time, but of nerve strength on the part of the young [illegible] before the switchboards.

Another kind of mental order [illegible] the principle of the concentration of attention, so important in education. To concentrate fully the attention means to attend [illegible] that one thing then receiving your entire energy and care. This principle is that on which the nervous system acts in controlling our bodily movements, and is, therefore, the only normal mode of action for our minds as well. *Fr[illegible] outer force of mind o[illegible]*

play seems to be the ideal condition of nervous economy and of efficient effort as well. "One thing at a time, and that done well, is as good a rule as any can tell," is a motto as scientific as it is ancient, for it makes not only for success, but for a large bank balance of nerve force. No habit which children can acquire or adults practice is more essential to true success than this one, for with this habit it is difficult for a person to be an actual spendthrift of his nerve strength, since every expenditure brings him in return something a little worth while, be it only the practice in mental power.

Extreme monotony is a frequent cause of fatigue. This form of prodigality in nervous force and endurance applies especially to life in general in the country districts, and to all occupations too narrow and unvaried to be natural. This wastefulness of nerve health is firmly based on physiologic and psychologic principles of the most primary kind and importance, on those especially underlying fatigue and the blood supply of the different parts of the body. Owing to the technicality and complexity of these relations, however, it is not fitting to do more in this place than to suggest its importance and to insist that normality of the nerves is dependent on *frequent change*, leading to a re-creation of nervous efficiency. No school and no shop realizes practically as yet the great importance of this matter from a purely economic point of view, not to mention the human side, quite as important in the end.

Another conspicuous way in which a variable amount of our capital of nerve force, especially in the cities, is needlessly dissipated, is by the useless overstimulation of the senses. For practical purposes the senses most concerned for the majority of people are hearing and vision, the former especially. The nervous income is wasted unduly, and far beyond general understanding, in short, by too many loud and disturbing sounds: fire alarms, locomotive whistles, automobile horns, carts, rough and hurried milkmen, bells, vibrating trolley-car trucks, etc., almost without end. These and other loud sounds keep the nervous system irritated, for most of them are purely noises with nothing pleasant about them, save to the boyish irresponsibles that produce or allow them. Moreover, these startling noises, besides preventing sleep and overstimulating the nerves, are producing deafness in multitudes of us, the ear specialists say, and this partial deafness serves as an important secondary source of nerve strain.

In a wholly similar way parts of our cities, and many of our playhouses, etc., are overlighted by overbright and flashing signs, and the eyes and nerves strained by moving pictures, flash lights, etc. To the numerous nervous systems that are none too strong, these and such as these are more important for harm than they may at first thought seem to be.

A paper to-day on fatigue would be likewise incomplete did it ignore the recent work of Professor Max Verworn of Bonn on the basal phenomena of fatigue. See his "Irritability" (New Haven, 1913) the enlargement of lectures delivered at Yale in October, 1911, where (p. 187) he summarizes the research related to fatigue in these words: "Just as all living systems show a refractory period after an excitation, in which irritability is reduced, all living systems are likewise capable of fatigue. Both are most intimately connected and are based fundamentally on the facts of metabolism. [Hence is fatigue always an abnormal condition as was said above, for of course under normal circumstances anabolism equals metabolism.]

An exciting stimulus disturbs the metabolic equilibrium of rest by suddenly bringing about increased decomposition of certain substances. During and directly after the breaking down, irritability is reduced in the same degree as the amount of substances required for disintegration in response to a succeeding stimulus is decreased, and the quantity of the decomposition products is increased. This is the refractory period. By the metabolic self-regulation in accordance with the principle of chemical equilibrium, the original metabolic equilibrium is restored after every excitation. Irritability, therefore, increases in the same measure as this occurs, that is in the form of a logarithmic curve, until it again reaches the specific degree of irritability of the particular system. The refractory period diminishes. If the process of disintegration and self-regulation are delayed, either by want of substance necessary for breaking down or the accumulation of decomposition substances, the refractory period is prolonged and the response to every further stimulation decreased, that is the system is fatigued.

In all aërobic organisms the retardation of the course of excitation and self-regulation under a continuous influence of stimuli is a result of the relative want of oxygen. The processes of oxidative disintegration are prolonged and restricted by relative deficiency of oxygen and merge more and more into anoxidative decomposition. The products of oxidative and anoxidative decomposition accumulate. Both factors decrease the strength of the response after energy stimulation. Thus the want of oxygen leads to reduced activity."

This metabolic statement of the protoplasmic conditions of fatigue is gratifyingly complementary to the more energistic mode of considering it such as McDougall has expressed in the article referred to above. The matter is of course extremely complex and only its outside edges have been as yet crossed by anyone. Fatigue, for example, is intimately correlated with the euphoria-dysphonia balance underlying all behavior. For a brief discussion from this point of view see an article ("Certain Further Factors in the Physiology of Euphoria") in the *Psychological Review*, xxi., May 3, 1914, by the present writer.

George V. N. Dearborn.

Fat-metabolism, Disturbances of.—The normal and pathological fat-metabolism of the cells has received an immense amount of study during the last decade, and the views formerly held have been considerably altered as the result of such studies, although we are still far from a satisfactory solution of all phases of the problem. Fat-like substances (lipoids or lipins) occur in all of the body cells, partly in an invisible form and partly morphologically visible and capable of microscopic demonstration. Morphologically visible fat is found in the cells of adipose tissue, in liver cells, epithelium of the intestine, gall-bladder, sweat-glands, sebaceous glands, salivary glands, adrenals, kidneys, cartilage, etc. Other tissues and organs that show no fat on microscopic examination may have a fat-content equal to 5–25 per cent. of their dried substance. The presence of fat in the cells is shown by the occurrence of highly refractive (singly and doubly) droplets within the cells that are insoluble in acids and alkalies, but dissolve in alcohol, ether, or chloroform. With Sudan III or Scharlach R. the droplets are stained orange or red; indophenol stains fat blue. When these droplets contain oleic acid or oleates they will reduce osmic acid to OsO_2, giving the fat-droplet a black color. The presence of soaps and fatty acids may be demonstrated by Benda's method (formol fixation, Weigert's copper-fluorchrom mordant, Sudan III and hematoxylin). Nile-blue sulphate stains fat red and fatty acids dark blue. The polarization microscope should be used for the differentiation of singly and doubly refractive droplets (isotropic and anisotropic lipoids). The invisible fat of the tissues is either in such fine particles that it cannot be demonstrated, or it is dissolved in the cell plasma or combined in such a way that it cannot be demonstrated until a chemical deconstitution of the cell takes place. By means of Ciaccio's method it is possible

to demonstrate microscopically the invisible intracellular lipoids.

The visible lipoids (lipins) of the body cells belong to four classes: 1. Neutral fats or glycerin esters (singly refractive); 2. cholesterol esters (doubly refractive); 3. other intravital doubly refractive lipoids of unknown nature; 4. myelin (autolysis and postmortem changes only). The fats of adipose tissue and liver-cells, as well as of other cells that act as containers of fat-droplets, are composed of singly refractive glycerin esters. The anisotropic cholesterol esters are found normally in the epithelium of the gall-bladder, the adrenal cortex, lutein cells, interstitial cells of the testis, and in the atrophic thymus. They appear pathologically chiefly in degenerative processes and chronic inflammations. They are distinguished from the neutral fats by their double refraction. They stain more yellow than red with Sudan III, and grayish rather than black with osmic acid. With the ordinary microscope the other intravital lipoids may be recognized by their bright strongly refractive (anisotropic) droplets or crystal-like forms. They stain with the fat dyes, and differ from the neutral fats in that when treated with acid chromate solutions they become insoluble in the ordinary fat solvents and can be stained in sections with Sudan III (Ciaccio's method). They represent in a large part the lipoid droplets formerly called *myelin*. This term is now applied only to the lipoid droplets arising in the process of autolysis and postmortem degeneration (postmortal myelin decomposition), that are chemically different from the intravital lipoids. They probably arise from the disintegration of the phosphatide-like constituents of the nuclei and protoplasm. They are not doubly refractive but swell up in water to form the so-called myelin figures. In differentiation from the intravital fats and lipoids they stain with neutral red.

The normal fats of the body may be divided into the *labile* or *deposit fats* and the *stable fats*. The *labile fats* are glycerin esters (triglycerides of oleic, palmitic, and stearic acids). They represent the fat of the panniculi, liver cells, etc., in fact, all of the fat that is stored up in cells to be removed quickly for nutritive purposes should the need for it arise (fasting, starvation). This fat is brought to the cells and removed from them by the blood, in which the fat occurs as a very fine emulsion or dissolved as soaps through the action of a ferment (lipase) found in the blood. The amount of fat in the blood may be so great as to appear as lipemia (diabetes). In the taking up of the fat from the blood the droplets appear in the cells in a more or less regular arrangement suggesting a connection with definite cellular elements (plasmome theory). Fats fed to the body may preserve their chemical characteristics after passing through the blood and being taken into the cells (mutton fat stored up by the dog, etc.). The *stable fats* are intrinsic constituents of the cell molecule (*intrinsic fat*) and are not removed for nutritive purposes during fasting or starvation. They consist of the cholesterol esters and other doubly refractive lipoids, and vary greatly in character and amount in different tissue cells. In animals that have starved the intrinsic fat of the cells (muscle, cartilage, etc.) shows no decrease in amount.

The processes of normal fat-metabolism are so complicated and so little known that it seems hardly possible at this time to give any satisfactory discussion of pathologic fat-metabolism. As a matter of fact, we know but little about it. Formerly our conception of pathologic fatty changes seemed very simple and clear, when we considered them as consisting only of two classes, *fatty infiltration* and *fatty degeneration*. Virchow's conception of the latter process as a splitting up of the albumin molecule with a new formation of fat is no longer tenable. We know now that in the so-called fatty degenerative processes the fat varies in kind and [illegible] taken up by the [illegible] invisible intrinsic [illegible] the result of a [illegible] cells, or it may be [illegible] processes. Still the [illegible] and degenerative in [illegible] injury, and can be [illegible] is, therefore, no good [illegible] *degeneration* should not be [illegible] fatty changes in which the [illegible] type; otherwise we must resort to the use of such terms as *degenerative fatty infiltration*, which [illegible] the whole ground of degenerative processes characterized by the appearance of fat in the cells. Nevertheless, the majority of the text-books at the present time divide *fatty change* into [illegible] and *degenerative fatty* [illegible] tion is much more unsatisfactory than the old terms fatty infiltration and fatty degeneration. Various new terms are entering the literature to indicate the nature of the fats found in these processes: *liposis*, the presence of neutral fats in the cells; *lipoidosis*, the presence of anisotropic lipoids; *lipo-lipoidosis*, a mixture of both neutral fats and [illegible]

Kawamura has attempted to classify the pathological disturbances of the fat-metabolism from the standpoint of the chemical nature of the fat, the significance of the process for the cells affected, and the origin of the fat, as follows:

I. Exogenous fat-formation—fat-storage [illegible] (fatty infiltration).
   1. Normal fat-storage (glycerin cholesterin and lipoid steatosis).
   2. Pathological fat-storage with the same chemical varieties.
      A. From extracellular causes: (*a*) Fat-storage through feeding; (*b*) transportation of fat; (*c*) local fat-absorption; (*d*) fat-retention.
      B. From intracellular causes: Fat-storage (*a*) as the result of specific increased cell activity (progressive fatty infiltration, local or general lipomatosis); (*b*) from diminished cell activity (degenerative fatty infiltration).

II. Endogenous fat-formation—invisible fat becoming visible—myelinosis (fatty decomposition).

With our present unsatisfactory knowledge of fat-formation such a classification as Kawamura's cannot be taken as final; and, moreover, it does not correspond to the prevailing views concerning the two-fold nature of the microscopic appearances classed under "fatty degeneration." The most practical course is to retain the old terms "fatty infiltration" and "fatty degeneration" from the standpoint of microscopical appearances alone, completely discarding the old idea that fatty [illegible] means the formation of fat from cell protein, since at the present time there is no proof that such a conversion ever takes place, although theoretically it is possible. With the anatomical [illegible] for our classification *fatty infiltration* would be defined as an accumulation of fat in cells that structurally are normal, the nuclei staining well and the [illegible] lets fused together to form one or a few [illegible] lets; while *fatty degeneration* is the appearance or accumulation of fat in [illegible] cells, as shown by changes in nucleus and cytoplasm, the fat-droplets not fused into one large droplet, but lying as small droplets in the granular [illegible] cell ("ground-glass appearance"). In fatty infiltration the fat is brought to the cells and stored up through the action of the cell lipase or taken up by phagocytosis. In fatty [illegible] the fat may also be brought to the [illegible] and degenerative fatty infiltration), or the normal combined or invisible fat becomes visible as the result of [illegible]

The taking-up of fat by injured cells may be brought about by an interference with oxidation; when oxidation is lowered by any means the processes of cell disintegration and the taking-up of fat by the lipase may go on unchecked. In fatty infiltration the total amount of fat in the cells is increased; in fatty degeneration it may be increased, or remain normal (or less than normal), according to the character of the process. In both cases the fat may be either isotropic glycerin esters or anisotropic cholesterol esters.

Fatty Infiltration.—An accumulation of fat from the blood under the influence of the cell lipase in cells that show no severe injury characterizes this pathological disturbance of cell metabolism. It is a quantitative change of a normal process; the fat comes from outside the cell and is taken up as such or in the form of its components. The fat thus stored up in excess is usually a glycerin ester, but cholesterol esters may also undergo such a pathological infiltration. In general the causes of fatty infiltration are to be sought either in an increase in the fat-building metabolism, or in a decrease of the oxidative powers of the cells so that fat is not burned up but is accumulated. The specific causes are varied: overfeeding, lack of exercise, anemia, cachexia (tuberculosis), inherited tendency, poisons reducing oxidative activities (alcohol, chloroform, iodoform, bacterial poisons, etc.), disturbances of internal secretion (loss of pituitary function, castration), etc. The tissues chiefly affected in fatty infiltration are the adipose tissues (panniculi) and the liver. The fatty capsule and pelvic tissues of the kidney, the intermuscular septa, connective tissue of myocardium, the stroma of pancreas, mamma and salivary glands may also show fatty infiltration. The condition may be general (obesity, lipomatosis, adipositas) or local. The fat appears in large droplets that may entirely replace the cell protoplasm, the cell showing no other signs of injury. In the fatty infiltrations of all the organs and tissues except the liver the fat is always in connective-tissue (adipose) cells; only in the liver is the fat of infiltration found in the parenchymatous cells.

In fatty infiltration of the kidney the fat is found in the capsule and submucous connective tissue of the pelvis; in fatty infiltration of the pancreas it is found in the stroma cells; in fatty heart the fat is found in the connective tissue of the epicardium and in the connective tissue of the myocardium, extending in along the vessels, and sometimes reaching to the endocardium, etc. In the kidney, pancreas, mamma, voluntary muscles, etc., the fatty infiltration is often secondary to an atrophy of the essential elements of the organ or tissue (fatty atrophy, adipositas ex vacuo). Fatty infiltration of the liver occurs as a result of an increase in the labile fat taken in by the body (overeating), and as a result of decreased oxidative activity (chronic alcoholism, anemia, tuberculosis, etc.). The infiltration usually shows first in the cells of the periphery of the liver lobules, but in some cases the central zones of the lobules are first involved. In marked cases practically every liver cell may become a fat-cell without a trace of liver-cell protoplasm remaining. The nuclei are pushed to the periphery of the cell, but may stain well. The fat is brought to the liver through the portal vein and hepatic artery as nutritive fat, but the liver may also receive fat from other fat-depots that give up fat into the blood (phosphorus poisoning). The feeding of foods rich in cholesterol may produce great numbers of anisotropic droplets in the liver, adrenals, and aorta (cholesterol steatosis). In the obesity and fatty infiltrations of hypopituitarism there is also a cholesterol steatosis of the liver and adrenals.

The results of fatty infiltration are lowered function and ultimate atrophy of the parenchyma of the organ or tissue involved. The most extreme degree of fatty infiltration of the liver may exist, however, without any clinical appearances of altered hepatic function. Fatty infiltration of the heart increases the work of this organ, and a general passive congestion may be produced.

With fatty infiltration may be included the absorption fatty infiltration seen in wandering cells and phagocytes in the neighborhood of fatty emboli, areas of necrosis in central nervous system, border of infarcts, and necrotic areas, etc. Such phagocytes filled with fat-droplets are known as fat-granule cells. An absorption of cholesterol-ester fat takes place also in the epithelium of the gall-bladder from the bile.

Fatty Degeneration.—Fatty degeneration is a severe injury to the cell, characterized microscopically by the appearance of small droplets of fat (either isotropic or anisotropic) among the granules of the disintegrated cell protoplasm. The nuclei are more or less affected. The fat may be nutritive fat taken up by the disintegrating cells from the blood; or it may be brought to the latter from other organs or tissues that have given up their fat into the blood. In fatty degenerations of this kind the affected organ may show an increase of fat (heart, liver, etc.). In other cases no fat is brought to the disintegrating cells, but the fat-droplets arise from the liberation of the masked intracellular lipoids, the invisible fat becoming visible (phanerosis). Organs undergoing such a fatty degeneration may show microscopically an apparent great increase in fat, but the total amount of fat contained may be no greater than normal or even much less. In the case of the liver, heart-muscle, and pancreas fatty degeneration is usually an infiltration of neutral fat from the blood into damaged cells, in addition to some liberation of invisible fat and the fat-content is therefore increased. In the kidneys, adrenals, nervous tissues, voluntary muscles, and spleen fatty degeneration is nearly always the result of the liberation of the masked intracellular fat and lipoids through autolytic changes and the fat-content is normal or less than normal. In this second form of fatty degeneration the fat-droplets are usually anisotropic, consisting of cholesterol esters and other forms of lipoids, fatty acids, and soaps.

Fatty degeneration is caused by any marked decrease in oxidation and by poisons that lower oxidation or cause cell disintegration. Local or general anemia, asphyxia, various poisons, particularly phosphorus, chloroform, alcohol, arsenic, and bacterial toxins, fever, and poor nutrition are the most important causes of fatty degeneration. In general anemia there is always a more or less marked fatty degeneration of the heart, liver, kidneys, vascular endothelium, and other organs. Local disturbances of circulation cause fatty degeneration of the anemic area. Around the border of anemic and hemorrhagic infarcts there is a zone of cells showing fatty degeneration. Cells whose normal environment is changed show a fatty degeneration. It is common in wandering cells. It is also a very common change in tumor cells, partly because of the poor blood supply. Of the poisons producing fatty degeneration phosphorus is the most important; in phosphorus poisoning the liver, heart muscle, kidneys, blood-vessels, and voluntary muscles may show the most extreme change. In arsenic poisoning the degeneration is less severe and more irregular in occurrence. Fatty degeneration is of frequent occurrence in the acute infections, involving particularly the heart, liver, kidneys, vascular endothelium, and spleen. It varies in location and degree according to the character and severity of the infection. It is caused partly by the toxins, partly by the fever, and partly by changes in the circulation.

Organs showing a fatty degeneration are cloudy and lighter in color, grayish to yellowish. The fatty

change is often localized in spots or streaks following the course of the veins, giving rise to the so-called "tiger heart." In the kidney the fatty degeneration is often localized in the convoluted tubules. In the liver the central zone of the lobules usually shows fatty degeneration first; in extreme cases the entire lobule may show it. Cells farthest removed from the oxygen supply suffer the change first. In the heart the change is often most marked just beneath the endocardium. The intima of the aorta and great vessels may show lines of fatty change running parallel to the long axis of the vessel, corresponding to points of greatest tension or friction. Fatty degeneration is also an essential part of atherosclerosis. The cells of pneumonic exudate, old pus, tubercles, etc., also undergo fatty degeneration.

The essential microscopic feature of fatty degeneration is the appearance of degeneration. When the damage is not great the condition is reparable and resolution and recovery may take place. If the structure of the cell and that of the nucleus are badly injured the cell undergoes necrosis, disintegrating into a fatty detritus (soft caseation). Slight degrees of fatty degeneration of the heart muscle may, however, be sufficient to cause death from cardiac dilatation and acute insufficiency. A. S. Warthin.

Fat Necrosis.—See *Pancreas, Diseases of.*

Fats constitute one of the three great classes of organic foodstuffs. They are composed of carbon, hydrogen, and oxygen. Chemically the fats may be defined as combinations (esters) of glycerol and fatty acids (triglycerides of fatty acids). Upon decomposition, as during digestion, they yield glycerol and soaps which are absorbed and ultimately furnish energy to the body. See *Aliment.* F. P. U.

Favus.—See *Tinea Favosa.*

Fayrer, Sir Joseph.—Born at Plymouth, England, on December 6, 1824. He was the second son of a family of eight children, his father being a Commander in the Royal Navy. Like most children born in the Navy his early life was spent in many countries; his early education, however, was mainly obtained in Scotland and on the Continent. In 1840 he desired to go to sea, after finishing a course in engineering, but while on a visit to Bermuda with his father, an outbreak of yellow fever drew his attention to the importance of the profession of medicine, and he immediately began his studies preparatory to obtaining a degree. In 1844 he entered the Charing Cross Hospital in London, and in due course became House Surgeon to the Westminster Ophthalmic Hospital. He also studied at King's College, London. In 1847 he was admitted a Member of the Royal College of Surgeons, which marked his entrance into the medical profession, and in the same year he was appointed Assistant Surgeon on H. M. S. *Victory.* In 1849 he was transferred to the Army, and became Assistant Surgeon to the Royal Artillery at Woolwich, but was shortly transferred to the Bengal Establishment. India became the scene of the work to which he devoted his life. Here it was that as Assistant Surgeon in charge of the Field Hospital during the Burmese war, he obtained an intimate knowledge of tropical diseases, sunstroke, etc. He became Residency Surgeon at Lucknow, a post given to the Assistant Surgeon who rendered the most approved service during the war. Fayrer held this post all through the siege of Lucknow, returning to England on sick leave in 1858. He spent his year of furlough in study in the University of Edinburgh, where he took his degree, and was also elected a Fellow of the Royal Society and of the Royal College of Surgeons of that city.

In 1859 he returned to India and became Professor of Surgery in the Medical College of Calcutta, later becoming President of the Medical [illegible] University. He [illegible] appointed a member and [illegible] of the Indian Medical Board [illegible] Secretary of State for [illegible] General, and was elected to the Fellowship of the Royal College of Physicians. In 1875 [illegible] the Prince of Wales on [illegible] March, 1876, was created a [illegible] Star of India. In 1878 he [illegible] Royal Society, and the following year [illegible] Fellowship of the Royal College of Surgeons [illegible] land and the degree of LL. D. from the University of Edinburgh. He was created a Baronet in 1896. He was the recipient of numerous honors from medical societies of Paris, Rome, Lisbon, and [illegible] ber of the Academy of Science and of the College of Physicians of Philadelphia. He spent the later years of his life at Falmouth, England, where he died on May 21, 1907.

During a more than busy life, spent on battlefields as well as in universities, Fayrer found opportunity to contribute much to medical literature. He wrote freely in the medical journals, and contributed the articles on sunstroke and on climate and fevers of India in Allbutt's "System of Medicine"; he also rewrote the chapter on tropical liver abscess in Murchinson's "Lectures on Diseases of the Liver" (third edition). The article on sunstroke in the "Twentieth Century Practice of Medicine" is from his pen. In 1866 he wrote "Clinical Surgery in India"; in 1882 he published his work on "Climate and Fevers of India"; in 1888 "Epidemiology of Cholera" was published. Among the best known of his works is "Thanatophidia of India" and "Recollections of My Life" published in 1900. His "Preservation of Health in India" was written in 1894. E. L. J.

Fear.—See *Phobias.*

Feces.—The term "feces" is applied to the excrementitious substance that normally leaves the body through the anus. The material consists of the waste from the intestinal walls and the unabsorbed residues of the various secretions into the alimentary tract, together with an admixture, in varying amounts, of undigested and partially digested food, of bacterial residue, and at times such adventitious substances as may be taken into the alimentary canal *per os* and which are not absorbed. The common idea that the feces in health consist chiefly of food residue is not sustained by the results of recent investigations.

After the intestinal contents have passed the ileocecal valve, they rapidly take on the characteristic consistence, color, and odor of fecal matter, being altered by the absorption of the liquids and soluble substances, as well as, to some extent, by the [illegible] tion of putrefactive and fermentative proces[illegible] admixture with the strongly alkaline secret[illegible] large intestine. The extent of these changes [illegible] influenced by the rapidity with which the contents pass through the colon.

Physical Characters.—The *quantity* passed in twenty-four hours varies greatly, but is estimated to average 120–200 grams, [illegible] diet. It is dependent to some extent [illegible] and quality of food eaten, but is [illegible] the condition of the digestive [illegible] tion and absorption, and the frequency of evacuation. As a rule the quantity of feces increases with the relative increase in the amount of vegetable food in the diet. It is probable that this is due largely to the greater resistance of vegetable [illegible] action and the subsequent stimulation of peristalsis by the undigested residues, and more es[illegible] phytins, with a resulting diminution of absorption.

In an infant fed on cow's milk the quantity is regularly considerably greater, even up to ten times, than the amount passed by a breast-fed babe. This is due not alone to difference in digestibility, but to a considerable extent to the much larger quantity of milk given in artificial feeding, which both adds to the quantity of undigested food residue and increases the residue from intestinal secretion and waste. The quantity of feces evacuated is occasionally increased by pathological products, including mucus, blood, pus, and serous fluid.

The *color* is normally derived from the intestinal secretions, notably from the bile, and under certain conditions is also very considerably influenced by the food, the stools of a mixed diet usually being a medium shade of brown, those of a meat diet dark to blackish-brown, and the evacuations following the exclusive ingestion of vegetable food being a light brown. The stools of an exclusive milk diet vary in color from orange to light yellow. The dark color is due to hematin, and to some extent to the compact, dry condition of the fecal matter. In particular instances the color may be modified by special coloring matters ingested with the food, as, for example, chlorophyl, derived from large quantities of green vegetables. Adventitious ingesta as, *e.g.* certain medicaments, may determine the color. Thus, calomel may cause a green coloration, probably by causing the presence of biliverdin, and bismuth or iron may each be reduced or may exceptionally appear as the black sulphide. Again, unusual changes in the intestinal contents may modify the color, as the growth of bacteria, producing pigment, notably green, or, as occurs frequently in infants, there may be a production of unusually strong alkalinity in the upper intestinal tract, causing the presence of biliverdin in the feces in quantities sufficient to impart a green color. Finally, there are the clay stools after complete suppression of the bile and the similar appearance in cases without jaundice due to the presence of excessive amounts of fat.

The *odor* of the fecal matter of adults is characteristic and is to be attributed to the presence of skatol and indol, and probably to other aromatic products formed by the putrefaction of the intestinal contents. When the passage through the intestines is rapid there may be little or no production of skatol, as in the rice-water stools of cholera, which are almost or quite odorless or may possess a distinctive odor, referable to cadaverin. The stools of an infant do not normally have a putrid odor, but if strongly acid they may have a rancid smell.

Normal stools are cylindrically *formed* and have a definite consistence. When the passage through the large intestines is rapid or the secretion into the bowels unusually abundant, they may become soft or even watery, while under opposite conditions they may be considerably hardened and assume the form of balls or very thin cylinders, these hardened masses being known as scybala. The so-called lead-pencil form is in no way indicative of intestinal stenosis, but is the rule when there has been complete abstinence from food, and may be caused by spastic or paralytic conditions of the large intestines.

After the exclusive ingestion of soft food the *structure* is usually homogeneous, while in feces of the various mixed diets hard and undigested portions of food may be distinguished—as, for example, seeds, fragments of fruits and vegetables, or fibrous tissue. Adventitious admixtures of foreign substances are occasionally observed, such as fragments of wood, pieces of quill, buttons and pins. The appearance in the stools of bits of food tissue, recognizable to the naked eye, sometimes results from digestive insufficiency, either mechanical or chemical. Insufficient mastication is the most frequent mechanical fault. A failure of the chemical processes of gastric digestion is followed by the appearance of bits of connective tissue, while insufficient pancreatic digestion leads to the presence of undigested muscle fiber. Either biliary or pancreatic insufficiency may be followed by the appearance of much fat. Food fragments are more abundant in diarrheal discharges, the material in some instances passing the entire length of the alimentary tract in a few hours and almost unchanged. In such stools pieces of meat may be seen or milk clots of various shapes and sizes. As a rule, the inner portion of formed stools is more recent than the outer, the passage through the intestines following the ordinary rule of flow, being more rapid in the center and retarded at the periphery.

Fecal matter has a certain *coherence*. If it does not contain evident food residue the mass usually does not crumble readily, when stirred with water, as do stools in which much food residue is present, particularly plant tissue and undigested casein. A large amount of fat increases the coherency, as does also in some instances much mucus, though possibly this is due to the accompanying fat.

Inspection of the alvine discharges occasionally reveals the presence of *pathological admixtures*. Blood, if from the lower bowel, is recognizable to the unaided eye, but, if changed by contact with the digestive juices, it merely imparts a dark color or tarry consistence to the stool. Likewise pus is recognizable only when it has been discharged into the lower part of the large intestine. The normal stool may contain on its surface visible mucus, but not in any considerable amounts. In catarrhal conditions of the intestines, however, the amount of mucus may be greatly increased, appearing either as a glassy layer surrounding the fecal matter, as in diseased conditions of the lower portion of the bowel, or mixed with soft feces, in which case the mucus adheres to a glass rod dipped into the evacuation; or, finally, it appears in watery dejecta as small floating particles, readily recognized. In membranous colitis mucus is passed in long strings or as a continuous, tubular membrane, sometimes dense and opaque so as almost to appear fibrinous. In cholera and to a less extent in some other conditions great quantities of serous fluid, a true transudate, are evacuated with the intestinal contents.

Microscopic Characters.—Microscopic examination of fecal matter reveals a mass of bacteria and detritus in which is embedded a greater or lesser number of recognizable morphological and crystalline elements, some being residue of food or adventitious ingesta, others being products from inhabitants of the intestinal tract, while still other such elements are those derived from the body itself and its secretions.

Vegetable cells and fibers of variable form may be encountered, some containing starch granules or masses of chlorophyl. Occasionally, especially in diarrheal stools and where there is a failure of pancreatic digestion, starch granules more or less unaltered are recognized in considerable number. They turn blue in contact with a solution of iodine. Rosenheim states that he could not detect 0.6 per cent.; hence it appears that less than one-half per cent. of starch cannot be detected with certainty by microscopic examination.

Of the residues from *animal food*, connective tissue may be present in variable amount, being increased when this class of food is ingested in large quantity, and when there is a deficiency of gastric digestion. Where such food has been sparingly eaten, the appearance of areolar fibers in notable numbers is nearly always indicative of deficiency of the chemical processes of gastric digestion. Elastic fibers, except to a very limited extent in the instances in which they come from swallowed tuberculous sputa, are derived from the food and are not indicative of any condition of disease. Partially digested bile-stained muscle fibers are nearly always found in the stools, still preserving their transverse striæ so as to be recognizable, though the general appearance of the fibers may be

much altered. They are not rendered more numerous by gastric deficiency but they are apt to remain bound together by bands of undigested connective tissue. A large increase on a limited meat diet is indicative of deficiency of intestinal digestion. Undigested milk clot is at times present in the excrement of adults, and is frequently seen in the stools of infants. They are recognized by the absence of structure, the presence of fat globules and protein, as indicated by microchemical tests, and the solubility of the coagulated protein in dilute alkali and its reprecipitation by acetic acid.

Fat, in the form of globules and as fat tissues, is occasionally seen, but is commonly present as needles, single or in clusters. These are probably fatty acids in combination with calcium and magnesium, alkali-earth soaps. They are present in enormous numbers in alcoholic stools and are regularly increased when there is a deficiency in the absorption of fat.

Cholesterin *crystals* rarely appear in the stools, this substance not being a normal constituent of fecal matter. Since it is usually present in meconium, in the stools of starvation, and in evacuations when digestion is arrested, its appearance in crystalline form is to be looked for in these conditions. Stercorin, into which cholesterin is normally converted in the intestinal tract, crystallizes in thin delicate needles and hence is distinguished with difficulty from alkali-earth soaps. Whether this substance appears in crystalline form in the stools is unknown.

Phosphate crystals are regularly seen in the microscopic examination of feces, either as wedge-shaped prisms, single or in clusters, of the neutral calcium salt or as the triple phosphate in its various forms (see under *Urine*). They are without pathological significance.

Calcium oxalate crystals are frequently recognized in fecal matter. They are in many instances derived from the food, but there is reason to believe that oxalate is at times formed in the fermentative and putrefactive processes of alimentation. In the light of our present knowledge its occurrence in crystalline form cannot be considered significant of any pathological process. Crystals of other organic salts of calcium are described as occurring in stools, the lactate in the discharges of children, appearing as sheaves of radiating needles, and the acetate and butyrate in the discharges of gastric and intestinal catarrh. The occurrence of amorphous particles or dumbbell crystals of calcium carbonate and of prisms or dumbbell-shaped amorphous masses of calcium sulphate is exceedingly rare and probably devoid of pathological significance. After the administration of bismuth black crystals appear in the stools; in shape they closely resemble hemin crystals.

Charcot-Leyden crystals are occasionally seen, most frequently when intestinal parasites, particularly worms, are present. They are also seen in typhoid fever and in catarrhal conditions of the bowel.

Of the *morphological elements* derived from the body epithelial cells are most frequently seen, as they are always present. Squamous epithelia come from the region of the anus, and are the least changed. The columnar variety is less frequently recognized, being much altered by partial digestion and abstraction of moisture. If in great numbers they point to intestinal catarrh, but are of no further diagnostic importance. The possibility of the presence of bits of neoplasm should always be borne in mind, but their recognition when such a growth exists is only occasionally possible. The casts of mucous enteritis and colitis frequently seem to be fibrinous, but microscopic examination shows that they consist of dense, more or less transformed mucus. Portions may be infiltrated with large numbers of small round cells. Blood, unless present in large amount, is recognized from the red corpuscles only when it comes from the lower portion of the rectum. Hemorrhagic stools frequently, however, contain [illegible] tochin, sometimes presenting a [illegible] structure, the crystals appearing in [illegible] after a hemorrhage and [illegible] the stools were passed. The [illegible] the so-called occult blood may be [illegible] tests. This, a small portion of [illegible] with water to a thin consistency, if much fat is present, extracted with neutral ether, then to the stool one-third the volume of [illegible] and the mixture shaken with a small portion of ether. In case of an emulsion, a few drops of [illegible] added. To this ether extract tincture of guaiac and ozonized turpentine or hydrogen peroxide are added which, in the presence of blood, yield a purple color. The test is more delicate and distinctive if three per cent. alcoholic aloin solution is substituted for the guaiac, when a red coloration indicates a positive result. It is even more delicate if the final test is made with 2 c.c. each of a saturated benzidine solution and hydrogen peroxide which yield an intense green color. Blood from the diet must be excluded. Pus corpuscles occur in dysentery, ulcerative processes, and where an abscess has emptied into the bowel. Leucocytes are usually much degenerated and, if present in considerable numbers, are usually significant of ulceration.

Parasites.—Feces contain lower forms of vegetable life which von Jaksch divides into two classes according to the manner in which they stain with iodo-potassic-iodide solution, viz., those that stain brown or brownish-yellow, and those that stain blue. The latter occur in relatively small numbers in health. Moulds are rarely present in fecal matter, only the thrush fungus being occasionally seen, and then in children with thrush. Yeast cells are very common, being present even in the stools of breast-fed infants. They are more abundant in the acid stools of children. The fission fungi, chiefly bacteria, probably in most instances constitute the greater portion of the bulk of fecal matter, occurring in enormous numbers, a milligram containing on the average several hundred million bacteria, of which only a relatively small number, one thousandth or less of the total, are living as judged by growth in culture media. Animals thrive in the absence of these forms of life in the intestinal contents, and they are not present during fetal life, yet their presence is probably not without benefit. On a strict milk diet the number rapidly diminishes. In the stools of infants the bacteria commonly present are the *Bacillus coli communis* and the *Bacillus lactis aerogenes;* they give rise to acid fermentation with the production of acetic and higher fatty acids and occasionally formic acid, but they do not occasion a true putrefactive process. The varieties in the stools of adults are very numerous, more than fifty species having been identified, a number that does not at all adequately express the many species that probably are present under all possible conditions. It is generally accepted that the colon bacillus is the most constant inhabitant of the lower bowel, and with it are several of the different species active in putrefactive processes. Herter, a few years ago, called attention to the bacterial flora of early childhood in cases of arrested development which he termed intestinal infantilism. These cases were characterized bacteriologically, by the overgrowth and persistence of types belonging normally to the nursling period, the dominant bacteria being Gram-positive organisms belong to the groups which he designated as the *Bacillus bifidus* type (the *Bacillus infantilis* type (observed by Kendall) and the coccal type, with the noteworthy absence of *B. coli* and *B. lactis aerogenes*. Under [illegible] normal growth is secured and [illegible] established. For an account of the individual species and of the pathogenic bacteria, see the article on *Bacteria* and those that treat of the various diseases. Animal parasites of various [illegible]

Invertin is said to accompany diastase in the stools of infants. A proteolytic ferment, which is apparently trypsin that has escaped destruction in its rapid passage through the bowel, is reported to be present in diarrheal discharges.

In the study of the digestibility or utilization of a definite food or dietary, it is important to distinguish the fecal matter containing the residue from this particular ingested material. The *separation of the stools* thus becomes an important part of the experimental observation. This is accomplished by the ingestion, at the beginning and end of the experimental period, of material which so marks or characterizes the fecal discharge as to render possible a mechanical separation, both from the fecal matter preceding and from that immediately following. A considerable number of substances have been employed for this purpose, including in dogs bone, silica, and cork, and in man lampblack, milk, and carmin. Perhaps the most satisfactory procedure is to limit the meal immediately preceding the period of the special dietary, and also the meal immediately following, to milk, with which, at the same time, several gelatin capsules containing lampblack are to be taken. In the separation advantage can then be taken both of the salve-like consistence of milk stools and the dark color imparted by the lampblack. In many instances this separation is very satisfactory, but in diarrhea, and particularly in constipation with formation of scybala, the boundary line is not always well marked.

After the feces corresponding to a definite period have been obtained, it is then desirable to distinguish what portion of the material is residue from the ingested diet, and what is waste from the intestinal tract. The distinction between the *metabolism residue*, as these products are called, and the food residue is a matter of extreme difficulty, and although it has received much attention, there is no method known at the present day that serves to accomplish this end, except under definite and restricted conditions. The procedure of estimating the metabolic products in the feces of starvation and deducting this amount from the total is inapplicable, since the metabolic products are increased with the ingestion of food and are dependent upon its character and amount In many instances no effort is made to distinguish between metabolic and food residues, the total feces being deducted from the amount of food ingested and the difference, instead of being termed "digestible" food, being called "available" or "utilized" food, and the factors deducted being termed "coefficient of availability" or "coefficient of utilization." Evidently these factors represent the net gain to the body rather than the digestibility of the food.

The feces are at times the subject of special examination to ascertain the condition of the intestinal processes. The macroscopic appearance alone may indicate a diminution of the chemical or an increase in motor function, by showing an excess of fat or particles of food residue; but the microscopic appearances are of greater service to this end. When more exact knowledge is desired, the coefficients of availability of the nutrients of a given dietary of known amount and composition may be determined and these results compared with the coefficients in health. Ad. Schmidt and Strasburger have recommended different procedures that are of value in determining the utilization of carbohydrates. At the outset, after the ingestion of 0.3 gram carmin, the patient is put on a special diet, known as No. 2, consisting daily of milk, 1,560 c.c., four eggs, 100 grams zwieback, one plate barley soup (40 grams barley), one plate flour soup (25 grams flour), 375 c.c. bouillon, all containing 20 grams sugar, in combination with the more common diet of 60 grams chopped beef, and 250 grams mashed potatoes (potatoes 190 grams, milk 60 grams, butter 7 grams). In diet No 1 the chopped beef and mashed potatoes are omitted. No 3 consists of 1,690 c.c. milk, 2 eggs, flour soup, bouillon, and mashed potatoes as in diet No. 2, sugar 10 grams, milk rolls 225 grams, meat (cutlet) 150 grams. The diets are seen to contain carbohydrate in increasing amounts from 1 to 3 and successively in more difficultly utilizable form, as well. For most cases either or both 1 and 3 will be found advantageous in addition to 2. After the disappearance of the carmin, usually after an interval of three or four days, during which the diet is continued, the feces are submitted to a fermentation test, as follows: The fresh stools are mixed with water (usually two parts) to the consistence of a thick fluid, and the mixture is put in a fermentation tube of about 30 c.c. capacity and left at body temperature. The formation of gas in twenty-four hours to one-third the capacity of the tube is a weak reaction; to two-thirds moderate, and more than this strong. Five conditions determine the development of the reaction, namely, the presence of (1) starch, (2) nutritive material, (3) obligatory bacteria, (4) a diastatic ferment, and (5) the absence of a high grade of acidity. A late appearance of gas is due to putrefaction of the material, and is not to be given the same consideration as the early fermentation. Strasburger concludes that early fermentation with diet 1 is always pathological; with diet 2, is on the boundary, but is more frequently pathological; with diet 3, is normal, yet in the majority of normal stools does not appear. Only positive results are of diagnostic value. Under most conditions carbohydrate is the variable factor, and it is apparent that Schmidt's method is primarily directed to the estimation of the utilization of this class of nutrients. The same investigator has devised a method of measuring the bulk of undigested meat fiber in the feces after the ingestion of these same dietaries. The method consists essentially in determining the reduction in volume which the residue in the feces undergoes when submitted to the action of pepsin-hydrochloric acid. The value of the procedure remains to be determined.

ERNEST ELLSWORTH SMITH.

Fecundity.—This term signifies generative power or fruitfulness. It is sometimes used to signify *abundant* fruitfulness or fertility in reproduction. It is applicable both to males and to females, to nations as well as to individuals, and to plants as well as to animals. It is even used rhetorically concerning things or inanimate objects.

The fundamental factor to be considered in any study of fecundity whether in man or in animals is the ovary, and its size is not of so much significance as the number of ova which it may contain.*

The ovary in many species of fish is relatively large and contains an almost incalculable number of ova.

The ovary in mammalia is relatively small and when compared with that organ in fishes the number of ova which it contains is small. The ovary in birds is also relatively small. The average hen lays about 600 eggs during a period of four years, many ova not maturing, as is the case with all other animals.

The ovary in the human female, from first to last, contains an average of about 30,000 ova.

It seems strange that the ovaries in large animals, elephants, cows, buffaloes, etc., should be little if any larger than those in the human female, and also that there are vastly more ova even in the smallest ovary than can ever be utilized. Provision is thus made for lavish waste and loss, that the species may not suffer, whatever becomes of the individual. The same prodigality of resource is noticeable in the male reproductive element, the spermatozoon; of the

* De Vries has remarked that in the nucleus of the ovum all the hereditary predispositions of the organism are represented and they are reproduced by transmission to the other organs of the protoblast, thus giving rise to the hypothesis of intracellular pangenesis.

thousands of spermatozoa which may have the potentiality of fertilizing an ovum but one performs that function.

The subject of fecundity forms an essential part of the data of vital statistics and it is to be regretted that the collection of such valuable information has thus far been neglected in this country. In many of the States, especially the newer ones, it has been ignored entirely.

Let us first note the postulates which were enunciated more than a century ago by Malthus in his logical but severely criticised treatise on "The Principle of Population," for they are fundamental in the consideration of fecundity.

"1. Population is necessarily limited by the means of subsistence.

"2. Population invariably increases where the means of subsistence increase unless prevented by some very powerful and obvious checks.

"3. These checks and the checks which repress the superior power of population and keep its effects on a level with the means of subsistence are all resolvable into moral restraint, vice, and misery."

Causes which Influence Fecundity.—These causes may be favorable or unfavorable, they may be favorable to-day and unfavorable to-morrow. They may be grouped under three general headings, individual, social, and physical. The greatest number of the causes which bear upon this question are, of course, those which concern the individual.

Food.—Assuming that the first proposition of Malthus is valid we must regard food as the primary factor in the discussion of fecundity. Starving men and women are not only minus the impulse which prompts the sexual act but they are physically impotent, for the ova and the spermatozoa are vital structures and the conditions which impair the vitality of the other structures of the body during starvation necessarily apply also to them. Food may also be favorable or unfavorable to fecundity according as it is nutritious or innutritious and as it excites or does not excite sexual desire.

The former obtains with highly spiced and seasoned foods, with alcoholic liquors, etc. Of course the matter of individual susceptibility enters largely into a question of this kind, for foods like medicines vary in their effects upon different individuals. A time of abundant harvests is favorable to fecundity, not because it leads to enjoyment and excess as it often does among the savage and ignorant, but because it results in good nutrition, in abundance of labor, and in the elimination of worry in providing for the immediate future.

Nutrition.—This is, of course, intimately associated with the subject of food; fecundity is not favored when the nutrition of the male or the female is bad.

The tuberculous and those who suffer with other serious diseases are not without sexual desire, indeed that emotion is frequently accentuated by disease, but even if pregnancy occurs in those who are badly nurtured it will frequently end in abortion or at best in a living child which is so feeble that it will speedily succumb.

Unfortunately it has frequently been noted that an unhealthy father uniting with a healthy mother may beget a large family of children. (See Elderton, Galton Laboratory of Eugenics, University of London, Eugenics Laboratory Memoir No. 18.)

Desire for Offspring.—The regenerative power is not wholly dependent upon a desire for progeny, for instances abound in which there was either perfect indifference or positive repugnance to offspring and yet the offspring came with regularity and frequency.

On the other hand, those couples who are in good physical condition and have an eager desire for offspring are likely to get them. This is noteworthy among the Mormons, the Jews, the Mahometans, and others who see in a large family not merely the satisfying of a natural and proper inclination, but obedience to a religious conviction as well.

Condition of the Generative Organs.—It is a prerequisite to fecundity that the generative organs in both the male and the female be in a normal condition. Reproduction is impossible if these organs are undeveloped or absent in either sex. If they are overdeveloped there is usually increased sexual desire and increased probability of fruitfulness. If they are diseased the chances of fecundity are lessened.

Syphilitic organs may result in sterility or in offspring with greatly impaired vitality, and the same is true of some other diseases. It is a singular fact that when the ovaries are the seat of tumors, even of a very large size, and the uterus or the male organs of generation the seat of malignant disease the power of reproduction may remain. In idiots and imbeciles the generative organs are often defective or undeveloped and though procreation sometimes occurs (an idiot mother in a public institution was only recently reported as having six children, distributed in various other public institutions, each one representing a cost of $5,000 to the State to bring up to a useless maturity), it is by no means so frequent as some writers would lead us to fear. The absence of one ovary is in no respect a bar to fecundity as every ovariotomist knows. The writer removed an ovary from a well-developed woman after the rupture of a tubal pregnancy. In a year or two she gave birth to twins, and the following year to another child. Another woman, the Irish wife of a vigorous and well-developed Italian, gave birth to three children, then had a nearly fatal tubal pregnancy on the right side, then had two living children and a third still-born child at term. Then followed a tubal pregnancy on the left side which, after rupture, was successfully operated upon by the writer.

Disease.—The influence of tuberculosis and syphilis has already been referred to. Other diseases either in the male or the female may have a similar unfavorable influence, examples being the chronic wasting diseases, chronic metallic poisoning, disease resulting from the use of the *x*-ray apparatus, various diseases of the nervous system, especially those which are associated with paralysis, and even some of the acute infectious diseases.

The general principle has been stated that any influence which impairs the nutrition and the vitality in general will impair the vitality of the ova and the spermatozoa. If the given disease occurs in early life and is recovered from the reproductive power may be restored, but most of the diseases which have been alluded to occur in mature life and the more remote they are from the climax of the procreative period, that is from the age of thirty in the female and of thirty-six in the male, the less the probability that this function will be restored.

Temperament.—Indifference to family life and to the propagation of offspring has much influence upon fecundity. It was noted at the Eugenics Laboratory in London (1913) that this was a conspicuous cause of the lowered fertility in the energetic, intellectual, prudent, well-to-do classes in England at the present time. This is at least one of the causes why fertility is so comparatively infrequent among prostitutes. Pregnancy does occur among them and abortions are frequently practised, but the pregnancies are rare compared with the frequency of the opportunities which are offered. Measures for the prevention of impregnation are common enough among the higher grades of prostitutes, if the term is permissible, but not among the more depraved, and careless, and abandoned.

A cold, unresponsive, and passionless temperament in husband or wife or both is not necessarily associated with infertility. If such individuals are normally developed physically they are as competent

for procreation as those whose temperament is ardent; indeed more so than those whose temperament is ardent, but whose generative organs are defective, a combination which is not so very rare.

The chief reason why cold and sexually unresponsive husbands and wives are so frequently childless is that the sexual act is unattractive to them. They have no children because they are disinclined to use the means which are indispensable to the accomplishment of that end.

Age.—Age has much to do with the subject of fecundity and no phase of the subject has been more carefully studied than this. The fecundity of most women according to Matthews Duncan is greatest during the first years of the child-bearing period, reaching its climax at about the age of thirty, those who are under thirty being usually more than twice as fertile as those who have passed that age.

In Scotland, the fecundity of which has been carefully investigated by Matthews Duncan, though some of the wives from fifteen to twenty are sterile, the fertility of this group taken as a whole is very great. The highest initial fecundity is among those whose ages range from twenty to twenty-four, but it declines as the latter limit is passed. When women are married above the age of twenty-four the greater their age the greater the probability that they will be sterile; after five years of sterile marriage their chance of offspring is as one to seventeen.

While we have been unable to obtain comparative statistics of all countries it will be recalled that Scotland is a relatively cold country, and that maturity occurs later in cold than in warm countries. It would therefore seem probable that the greatest fecundity, initial or otherwise, in tropical or semi-tropical countries is in the five-year period between fifteen and twenty.

Quetelet, a profound student of this particular subject, places the maximum of fecundity in women as a whole prior to the age of twenty-six and Matthews Duncan states that the maximum in men is from thirty-one to thirty-three.

Lewis found that in Europe and Australia the maximum fecundity of women was between fifteen and twenty-four and that after forty-five it was very low. Of the illegitimate births in Scotland, which are 7.93 per cent. of the total number, sixty-five per cent. are born of mothers between the ages of twenty and twenty-nine, but their number is diminishing even more than the number of legitimate births. It is also interesting and remarkable to note that, according to the most recent statistics, eighty-two per cent. of all Scotch brides are ultimately fecund, forty-seven per cent. within the first year of marriage, and seventy-four per cent. within two years.

In some communities it is not unusual for marriage to take place with considerable frequency during pregnancy. Lewis says that among the peasants of Denmark thirty-nine per cent. of the children are born within seven months after marriage, and thirty per cent. within the same period in New South Wales.

Household Conditions.—When men and women are in good physical condition, ignorance, bad hygiene, and inferior home surroundings have a less unfavorable effect upon fecundity than might be expected, but on the other hand good home surroundings distinctly favor fecundity among the thrifty, the industrious and the well-to-do.*

One need only visit the slums and congested quarters of any large community, where the rooms are overcrowded, the hygiene bad, and the children swarming in the streets to prove the truth of these statements, and it must be remembered further that the resisting power of such children is low and their mortality great. When women are compelled not only to endure bad hygienic conditions, and bad food, but to look after the household and furthermore to go out and work all day, it is not strange if the child-bearing faculty becomes impaired. Such women, it is true, do frequently bear several children in rapid succession, but not a few of them succumb in early life to exhaustion and disease. Their fecundity, on the whole, is therefore inferior to that which better household conditions would give them.

With better household conditions, a greater degree of intelligence, and a greater sense of responsibility, preventive measures and self-control with regard to the sexual life are often regarded as essential to the welfare of the family, and fecundity is lowered. Of course this is one explanation of the constantly diminishing birth-rate among those who are in moderate and well-to-do circumstances in civilized nations, but it tends to maintain the quality of the stock and is a counterpoise to the deterioration which follows unrestrained child-bearing among the ignorant, the thriftless, and the vicious.

Vicious Habits.—Foremost among these is the use of alcohol and other narcotics. The use of alcohol is frequently associated with brutality particularly among the depraved and ignorant. Unrestrained sexual indulgence, irregularity and intemperance in eating and drinking, insufficiency of sleep, and criminal habits and practices of all kinds are factors which are not without influence, direct or indirect, upon fecundity.

The number of abortions and miscarriages which are associated with intemperance and brutality is very great, and while it is not maintained that the procreative faculty is abolished at once by these vices, for drunkards and syphilitics and criminals of all kinds do bear children, it is certainly curtailed in numberless cases.

The influence of gonorrhea in impairing the sexual organs in men and women is now unquestioned and thousands of women are sterilized annually by this disease alone. What is worse a large proportion of these cases occur in young women at the very beginning of married life and all hope of having offspring is effectually destroyed.

As to the influence of crime and vice in the propagation of great numbers of offspring the notorious Jukes family and a number of similar ones are frequently cited. The illustration is an impressive one, but it must also be remembered that in a far greater number of cases the vicious habit, *ipso facto*, cuts off the possibility of reproduction not only in the criminal but in those who are his victims.

The influence of such narcotics as opium is manifest among nations like the Chinese by many of whom it is used habitually. When it is used in this manner it frequently removes not only the power of procreation but the sexual desire as well. In this country the use of opium, cocaine, and other habit-forming drugs is said to be increasing to an alarming extent, and cannot fail to have a baneful effect upon the reproductive power of those who are its victims.

Occupation.—Any occupation which impairs vitality must affect fecundity, either directly or indirectly. An entire group of the so-called occupational diseases has recently been studied and classified, and they are among the most important developments of modern life. The mother who leaves her home and works in an unsanitary shop or factory, the young woman who works in a badly ventilated store or office, the man who is employed in a dark room or one which is artificially lighted, or in a chemical factory where he constantly inhales noxious gases, besides many in other unhealthy occupations, are all engaged in work which has an effect upon reproduction. In some cases, for example those who work with the *x*-ray apparatus, impotence which is probably irremediable has resulted.

These facts amply justify the interest which has been

* Elderton associates poor physique and low social value with large families and Heron (Draper's Research Memoirs) states that great fertility is not unusual with stock which is physically and mentally inferior.

excited in occupational diseases and in the sociological efforts which are being so generally devoted to the betterment of the surroundings of the daily task.

Wages.—It is an observation as old as Adam Smith and Malthus that increase of wages and abundance of work mean increase in population. This is doubtless true of those classes which are commonly called the laboring classes, though among many of the laboring people who are thriftless and ignorant the presence or absence of wages and work seems to make little difference in the regularity with which new babies appear.

An increase in income means, to many a man, the justification of marrying and having a family. It also justifies many prudent married couples in assuming the responsibility of adding to their families, though this also means more mouths to feed and more backs to clothe.

The result of increased wages may therefore be a very beneficent one in permitting the gratification of a perfectly natural desire for children.

In many countries children have long been regarded as an economic asset to the family, but as the labor laws throughout the world undergo modification and the rights of children are defended this asset becomes less and less valuable, for the children are becoming less and less convertible into income. This serves, to some extent therefore, as a check to those who would exploit the labor of their children, and will also serve as a check to population. That this is already true is shown by recent vital statistics in such large manufacturing centers as Birmingham and Glasgow.

The following are Elderton's conclusions in the Eugenics Laboratory Memoirs No. 18: (1) Wages ought to be directly proportioned to social value as measured by physique and mentality. (2) The size of the family should be proportioned, on the average, to the wages. In other words fertility has ceased to be coincident with economic value.

Preventive Measures.—It would be improper to overlook the influence which preventive measures exercise upon fecundity. The late Professor T. G. Thomas, in his wonderfully graphic lectures, used to say that women could be divided into two great classes in one of which the desire to have children was constant, while in the other the desire not to have them was equally constant.

There is no doubt that fecundity is enormously modified by the determination of men and women everywhere throughout the world that they will not have children, or that they will have no more than they want, or than they think they can bring up. This is particularly the case in civilized countries and leads to the use of measures of the most varied character for the prevention of pregnancy or for its interruption. The crudest and most barbarous means are sometimes adopted by women to interrupt pregnancy and they may be followed by serious or fatal consequences.

The trade of the abortionist is a lucrative and busy one in many communities, while in China and other countries which are less civilized the exposure of infants which are not desired is a cruel substitute for abortion. Happily the exposure of infants is becoming less prevalent everywhere and more reprehensible than it used to be regarded.

The prevention of pregnancy by artificial means is certainly less blameworthy than the practice of abortion, though it often exacts severe penalties from those who indulge in it. There is no doubt in the mind of the writer that it is often justifiable though to what extent and in what manner need not be stated at this time. It certainly does seem reasonable that those who are unfitted or unable to bear and nurture healthy children ought not to bring them into the world, with all their handicaps, to meet the distress and mishap which will be inevitable.

The sterilization of the criminal and the mentally defective is now a law in eight of the states of this country. In Indiana where the law has already been in operation several years it is said to have worked well. It seems reasonable that those who are already a burden to the community should not be permitted to add to this burden by procreating their debased kind. For certain classes of degraded criminals it would be desirable that even more drastic procedures than the simple ligation of the *vasa deferentia*, which is now practised upon defectives, should be carried out.

Causes of a Social Character.—Fecundity is also greatly modified, increased in some cases, diminished in others, by causes which are social or partly social in character. It is well to remember, as stated by Elderton, that if fertility is correlated with any antisocial hereditary character a population will degenerate with considerable rapidity. This is well illustrated in the decadent and decayed nations which have yielded to vice, luxury, disease, etc., notwithstanding the great fertility of more or fewer individuals among them.

Indifference.—A feeling of indifference for the responsibilities of bearing and bringing up children has prevailed in many communities from time immemorial and is coincident with a low birth rate. On the part of many it indicates a want of patriotism and upon this ground statesmen in different countries have repeatedly appealed to their fellow countrymen to overcome it. It is a common sentiment among well-to-do classes in this country and has formed the excuse for many sermons from a distinguished statesman on the folly of race suicide. It has been a common sentiment in France almost continuously since the Revolution, and France has had a diminishing birth rate almost continuously since then. It is a sentiment which is growing in Germany and is cause for serious consideration in all civilized countries. It has been counterbalanced in part by great improvements in hygiene and preventive medicine and particularly by a great and almost universal diminution, of mortality among infants; this however is palliative and not curative.

Divorce.—Akin to the cause which has just been alluded to is the increasing number of divorces in many countries. In spite of the rigorous and praiseworthy tenets of the Roman Catholic Church upon this subject the evil is spreading. It is a scandal and a disgrace in this country.

In the countries of central Europe, especially in Germany, it is associated with a diminishing number of marriages and a diminishing birth rate. In 1911 there were 15,780 divorces in Germany or twenty-four per 100,000 of population against twenty per 100,000 in 1906, while the number of marriages in 1911 was 7,800 per 100,000 against 8,200 in 1906. In Berlin the divorces in 1911 were ninety-six per 100,000 against sixty-two in the period from 1901 to 1904.

High Cost of Living.—This factor which is so conspicuous in this country exists also in many others. The cause need not detain us, it is sufficient to know that it exists. Unfortunately it is attended also with widespread luxury and extravagance on the part of those who are in easy circumstances, and with great discontent on the part of the poor. These are ominous conditions for they affect not only the welfare of individuals but of nations.

In the reign of Augustus, 200,000 Romans of mature age received enough corn from the government to subsist upon, and they had little else. Each had enough for an individual but not enough for a family, and it was the time of Rome's greatest prosperity.

Irregular Employment.—As in the individual so in the mass unsteadiness of employment in consequence of strikes and tariff discussions, overloaded markets, and social disturbances of various kinds always reacts upon the birth rate, and unfortunately it lowers the rate among those whose offspring is most desirable for

a community. The lazy and the thriftless and those who are without forethought or care for the future continue to breed and the additional burden of care for their offspring falls upon the prudent, the careful, and the well-to-do. It is such facts as these which justify preventive and even restrictive measures regarding procreation, in the minds of many thoughtful people.

Hygiene.—There is no subject to which more intelligent thought has been directed in recent years than that of hygiene. It means cleaner streets, better and better-ventilated houses and shops and factories, public baths, inspection of food, inspection of schools, prevention of disease, and a great many other useful measures. It has lowered the mortality rate in all civilized countries, it has reduced the mortality among infants to an extent that is really astonishing, and it has increased the average length of life.

It is probable that it has diminished rather than increased fecundity, especially in urban communities, but in this respect it certainly signifies improvement for it gives those who come into the world a better chance of remaining a while and under more favorable conditions than formerly.

Agricultural Life.—No occupation or manner of life is better adapted to result in health and the normal performance of the functions of the body than agriculture. It means not only abundant exercise of all portions of the body but the appropriation of an abundance of life-giving oxygen. It is not strange therefore that statisticians regard it as the form of life which is most favorable to fecundity. A century ago the majority of the population of this country were farmers, there were few cities with their allurements and their dissipations, and it is not strange that the population increased with great rapidity even apart from the great accessions which were subsequently derived from immigration. It was a common experience for a farmer to have a dozen children or more and the majority of them grew up to sturdy manhood and womanhood, and there is nothing unusual in this, for in new countries generally the same thing is observed, provided the climate and soil are good.

It may therefore be regarded as demonstrated and demonstrable that fecundity is at its best, both in respect to numbers and quality, in rural rather than in urban communities.

National or Racial Virility.—The quality of race stock differs in human beings, just as it does in animals, and shows the widest variations in the tenacity with which it holds on to life and reproduces itself. The virility of the Jewish stock is wonderful and also its power of reproduction even under adverse conditions, and the power of the Anglo-Saxon stock is similarly remarkable. Some of the barbarian and semi-civilized nations and races have shown wonderful reproductive power though lacking in other important particulars. The swarms of barbarians which overran Europe in the early centuries of the Christain era illustrate national virility, particularly under the stimulus of migration, and show that the simple impulse to live and reproduce is sufficient, under favoring physical conditions, for association with the greatest possible fecundity.

Malthus remarked that the natural fecundity of women is nearly the same in all parts of the world, though it is affected by various conditions in various countries and especially by late marriages. He also observed that a nation is in a precarious condition when there are fewer than four children as the product of the average marriage. The last statement, if true 100 years ago, when the general mortality was high, the infant mortality more than fifty per cent. and the average expectation of life much lower than now, can hardly be true at present when hygienic laws are so much more generally understood and obeyed.

Polygamy.—The natural supposition would be that polygamy and fecundity and overpopulation would be synonymous, but this is not the case, and it is far from the truth if polygamy means simply the indulgence of excessive sexual desire. The partriarchs in the Bible narrative were polygamous and had large families because that not only conformed to their desire but fulfilled the divine injunction which they believed was imposed upon them. The Mormons professed to have a similar religious conviction and as long as polygamy was permitted in this country they increased with great rapidity. Polygamy as a part of a social system is now outgrown and its practice in most countries is neither lawful nor desirable. Judging from its present manifestations it favors fecundity neither in men nor in women and it has so many objectionable features that its disappearance will be an advantage to the race.

War, Famine, and Pestilence.—Of course these calamities are unfavorable to fecundity. It is true that famine and pestilence are survived only by the fittest, but the physical condition of such survivors is not usually favorable to reproduction. After a period of rest subsequent to such calamities it has been observed that population increases with great rapidity. This is particularly the case after disastrous wars so that within a few years the loss in population may even be more than repaired. This is shown in the experience of the United States and Germany during the half century which has elapsed since the great wars in which they were participants.

Emigration.—This is always favorable to fecundity when the condition of the emigrants is improved by the change in their surroundings.

When a barbarous nation, in the middle ages, swarmed into a country which was better and less crowded than its own, it increased in numbers, at any rate for a time, and particularly if the new stock with which it intermarried was good.

The immigrants who came to this country from England in the seventeenth century raised large families and multiplied more rapidly, in all probability, than they would have done at home. Emigrants frequently encounter trials and hardships in their new homes but these may lead to the development of the finest physical and mental qualities and give unusual stimulus to their reproductive apparatus, as they did in the case of our early settlers.

Government.—When political conditions are good and government is stable there is, of course, more encouragement to raise a family than when these conditions are bad. But this alone seems to have had comparatively little influence on the population of many of the nations of the world.

The modern tendency in governments to pension the aged, to care for those who are sick and injured and provide employment for a larger portion of the population, all of which shows the inevitable trend to socialism, is bound to have a great influence on population in the future. These beneficent tendencies will remove from the minds of many the association of old age with the poor house and the fear of their inability to bring up children decently. It will doubtless take from some the feeling of independence and self-helpfulness, but there are thousands who have never had such feelings and such as they will marry and bear children which they would not have been so likely to do under the old conditions.

Causes of a Physical Nature.—Physical causes are also responsible for certain phases of fecundity and must not be ignored. They are few in number and can be briefly considered.

Soil.—It cannot be said that a barren soil is altogether unfavorable to fecundity for there are few portions of the world where the soil is more barren than upon some of our New England farms and yet a most virile and abundant population has been raised upon them. But a barren soil is not selected from

preference and the generous soil of our western country attracted the younger generation of those who had lived upon the old and rocky hill farms.

The effect of this migration upon fecundity has been favorable, on the whole, though owing to various social causes and tendencies the increase in population has not been relatively as great, excluding the accession of immigrants from foreign countries, as in the early days. We repeat that the agricultural life under propitious conditions, and especially in a new country, affords the greatest possible stimulus to fecundity.

Climate.—This influence upon fecundity is very potent, though extremes either of heat or cold are not conducive to productivity.

The Esquimaux seldom have more than one or two children and it is said that the reproductive power of the English residents in India is exhausted in the third generation.

The natives of the tropics in general are not so prolific nor so virile as those of temperate climates, the climax of productivity is earlier reached, there is less ability to resist disease, and life is shorter.

Temperate climates with moderate heat and moderate cold unquestionably offer the most advantageous conditions for vigorous manhood and vigorous reproductive power.

Season.—As a corollary to the foregoing it is manifest that the impulse to reproduction is not greatest in very cold nor in very warm weather, and certainly not in weather that is hot and moist, but when it is sufficiently stimulating to bring all the functions of the body to their greatest activity. Even certain days are believed to be favorable or unfavorable to fecundity, but if this were true it is not due to their place in the calendar but rather because they are neither too hot nor too cold, neither too wet nor too dry.

Multiple Births and Unusual Fertility.—Giving birth to twins or triplets at the first labor is not in itself a mark of unusual fecundity, for the reproductive power may be exhausted by one such experience.

The proportion of twins in the total of births is about as one to eighty, and a larger number than two at a birth is very unusual.

It is a singular fact, as Duncan has remarked, that deformities are frequent in those families in which twins are common, and that among imbeciles and idiots and their relatives, if they bear at all they not infrequently bear twins.

Duncan also draws the conclusion from his extensive obstetric experience that the whole history of twin births indicates imperfect development and feeble organization, in other words that twinning is a departure from physiological rule, and the departure is even more marked when triplets or quadruplets are produced.

Very young women are unlikely to have twins at the first pregnancy, but with older women such an occurrence is not infrequent. In general a woman's chance of having twins increases with each pregnancy, that is, as she approaches or passes the climax of fertility. Remarkable examples of great fertility in women have been reported from time to time, some of them bordering upon the marvelous and incredible. A fund of such information has been collected by De Bay (La Venus feconde, Paris, 1873) and this is our authority for the statements which follow.

Hippocrates and Galen reported cases occurring in Asia and Egypt in which from two to five children were born at a single birth.

Osiander reports the case of a woman who had two and three children at a birth, her daughter also bearing two and five at a birth. Her sister had borne thirty-three children when she reached the age of thirty-two. Another woman was the mother of fifty-three children, having borne one eighteen times, two five times, three four times, six once, and seven once.

Meckel tells of a peasant woman of average size, but with a large pelvis, who was the mother of thirty children by one man and fourteen by another.

Burdach tells of a man who was the father of thirty children, and of a workingman in London who was the father of forty-six by eight women. A peasant in Moscow, in 1782, is said to have had eighty-seven children by two women, and two negresses are said to have had twenty children each in four labors.

Elizabeth Powler is said to have had sixteen children twelve of whom married. When she died at the age of eighty-three she had 114 grandchildren and 228 great-grandchildren. Out of these came 900 children or about 1,250 in five generations. These stories are curious and interesting, if true.

Statistics of Fecundity in Scotland.—It would be impossible as well as undesirable in an article like this to make an exhaustive analysis of the fecundity of the various races and nations of the world, furthermore the statistics for such a study are not available. The next best thing is to take the vital statistics of some representative nation as a type or standard and draw comparative or approximate conclusions from them. There is no more virile nation than the Scotch and fortunately the statistics on fecundity for the cities of Edinburgh and Glasgow have been carefully elaborated by Matthews Duncan, and those of Scotland as a whole by Lewis and Lewis. (J. Matthews Duncan: Fecundity, Fertility and Sterility, Wm. Wood and Co., 1871. Lewis and Lewis: Natality and Fecundity, Wm. Wood and Co., 1906.)

We have already quoted from both these writers and shall add a few brief summaries.

I. (1) The fecundity of the mass of Scotch wives was found to be greatest at the beginning of the child-bearing period, gradually diminishing. (2) Their fecundity before thirty was more than twice as great as after. (3) Their fecundity declines rapidly after forty.

II. (1) The initial fecundity of women gradually waxes to its climax and then gradually wanes. (2) Initial fecundity is very high from twenty to thirty-four. (3) The climax of initial fecundity is at twenty-five.

III. (1) Nearly all women who are married from twenty to twenty-five are fecund. (2) The fecundity of women married from fifteen to twenty is greater than of those married from twenty-five to twenty-nine. (3) The climax of fecundity is reached between twenty and twenty-five. (4) The fecundity of the average woman is a wave which rises from sterility to its high mark and then gradually falls to sterility again.

IV. (1) The fertility in twins is greatest when the fecundity is least and *vice versa*. (2) The actual number of twins born to the mass of women in different pregnancies decreases as the number of pregnancies increases. (3) A woman is more likely to have twins with each succeeding pregnancy than at the one immediately preceding. (4) In most women the birth of twins indicated great fertility up to that time. (5) A woman who bears twins will probably have a larger family than one who is uniformly uniparous.

V. (1) The fecundity of the majority of husbands is greatest during the early years, then it declines but may persist to a late period. (2) Fecundity after sixty-four is low, under forty it is higher than from forty to sixty-four. (3) There is a definite correlation between male and female fecundity, the former being two to three years later than the latter.

VI. (1) Wives from fifteen to nineteen are most fecund with husbands from fifteen to nineteen, the fecundity diminishing as the husband approaches forty. (2) Wives from twenty to twenty-four are most fecund with husbands from fifteen to nineteen, their fecundity remains high with husbands to fifty-

nine. (3) Wives from twenty-five to twenty-nine are most fecund with husbands from fifteen to nineteen, their fecundity declines irregularly with husbands from twenty to fifty-four. (4) Wives from thirty to thirty-four begin to decline in fecundity, their fecundity is highest with husbands from fifteen to nineteen. (5) Wives from thirty-five to thirty-nine are most fecund with husbands from twenty-five to twenty-nine. (6) Wives from forty to forty-four are most fecund with husbands from twenty to twenty-four less so with husbands from thirty to fifty, least with those who have passed sixty. (7) Wives from forty-five to forty-nine have low fecundity.

VII. (1) Of brides, fifty-nine per cent. become pregnant in the first year of marriage, and ninety per cent. in the second. (2) Multiple births in Scotland are as one to 8,391, the majority of twin births occur in women over thirty. (3) More males than females result from the first pregnancy. (4) Of the total of births one-fifth are born of primiparous mothers. (5) The intervals between births in large families is usually two years.

ANDREW F. CURRIER.

Feeding, Artificial.—See *Alimentation.*

Feeding, Artificial of Infants.—See *Infant Feeding.*

Feeding, Forcible.—Forcible feeding means the introduction of food into the organism against (or without) the will of the individual. It is employed in two groups of cases: (1) In patients exhibiting a comatose or semi-comatose condition for a considerable period of time; and (2) in patients afflicted with brain troubles (insanity, melancholia), when they refuse nourishment.

The insane form the largest contingent of cases in which forcible feeding must be resorted to. Here it is the most important measure not only to prolong life but also often for the establishment of a cure, whenever this is possible.

In some instances small quantities of liquid or semi-liquid food are introduced into the mouth of the patient and the latter is told to swallow. In case this procedure is effective, enough nourishment may be slowly ingested in this way. But if this means fails, as it often does, or in patients who are not accessible to our exhortations, the principal measure of forcible feeding consists in the artificial ingestion of nourishment. The latter is performed in three ways: (1) Gastric alimentation by means of a tube inserted into this organ; (2) rectal alimentation; (3) subcutaneous alimentation.

By far the most frequently employed and the most efficient method of forcible feeding consists in the first measure. It seems that the stomach pump was used for this purpose long before its application in gastric affections as a therapeutic measure (Kussmaul, 1867); for in 1857 William Hamilton mentions the stomach pump as a well-known procedure in the feeding of the insane. The same writer had also introduced a new means of gastric alimentation by inserting a tube through the nostril into the esophagus and providing it with a funnel. This method is still used nowadays, and I may, therefore, be allowed to cite Hamilton in full. He says:

"Acting upon a method advised, in cases of trismus, of introducing into the nostrils a tube to the posterior fauces, through which nourishment may be passed to a point beyond voluntary muscular control, an instrument was constructed which was efficaciously employed on the twenty-fourth of June last. It consists of an elastic tube, twenty-four inches long, the size of a catheter, at the open end of which a funnel is attached. Near its end the tube is slightly curved. The curve is maintained by the introduction of a silver wire, two inches in length, one end being bent upon itself to preserve it in position, to prevent its impinging at right angles upon the posterior wall of the pharynx during the first stage of the process, and during the second keeps the tube from interfering with the glottis. The tube being adjusted, the operator pours through it nutritious or medicated liquids, which are immediately, by automatic action, conveyed into the stomach. This operation is not disturbed, owing to the length and flexibility of the tube, by any considerable motion of the patient's head."

Forcible gastric alimentation is performed in the following manner: A soft-rubber tube (regular stomach tube), provided with a connecting glass-piece at the outside end, is introduced, either by way of the mouth (when this is possible, or after keeping the mouth open by a gag) or by way of the nostril, into the stomach. A rubber tube with funnel attachment is next slipped over the glass-piece, and the apparatus is then ready for the reception of food. The latter, in liquid or semi-liquid form, is poured from a pitcher into the funnel, which at first must be somewhat lowered, in order to prevent the entrance of too much air into the stomach, and then afterward raised to about the level of the patient's face, until the whole quantity desired has been ingested. Then the entire apparatus is quickly removed after compressing the tube with the fingers in such a manner that no contents may escape from it while in the pharynx. It will be readily understood that assistance is oftentimes required during this procedure, especially when we are dealing with maniacal patients. The arms and feet of such a patient must sometimes be kept quiet by strong assistants. In patients who do not offer much resistance, a thin long catheter may be introduced into the stomach and left there for a week or so; we then have the canal always ready for feeding purposes. The apparatus described in the article on *Alimentation, Duodenal* may be employed, permitting the end to lodge either in the stomach or duodenum, as it appears best.

The amount and kind of foods to be introduced into the stomach can be varied. The principle is, to introduce liquid and semi-liquid food in sufficient quantity for the maintenance of life. As a rule a combination of milk and eggs beaten up together is the most important and most frequently used form of nourishment. F. Jolly recommends using one quart and a half of milk and three raw eggs for each feeding, twice daily. The milk can also be combined with cream, with somatose, or with plasmon, or indeed with any of the beef juices in use. A tablespoonful or two of sugar and some table salt may also be conveniently added. In the same manner meat powder, purée of brain, peas, etc., can be mixed with water or milk and introduced into the stomach.

Inasmuch as forcible gastric feeding permits us to utilize a great variety of foods, and especially a considerable quantity of them, it lies within our power not only to keep the patient in balance, but also sometimes to make him gain in flesh. Forcible gastric feeding is therefore the means par excellence for forcible feeding. The other two methods mentioned above—rectal alimentation and subcutaneous feeding—play here but an unimportant part. Rectal alimentation may be for a time combined with gastric alimentation when it is very difficult, on account of the patient's struggles, to introduce the tube into the stomach. Subcutaneous alimentation is still less important, as the amount of nutritive value introduced in this way hardly amounts to anything. William H. Murray recommends subcutaneous injections of olive oil (10–20 c.c.) twice daily.

MAX EINHORN.

Fees, Medical.—In the early history of the American Colonies, the practice of the healing art was chiefly in the care of the clergy. For several

years previous to their leaving England, many of the clergy took up the study of medicine, and for upward of a century after the settlement of New England, numbers of the native clergy were continually educated in both professions.

This condition of things caused any recognition of the physician's care for his patient to be in the nature of a gratuity, rather than a payment, as he was caring not only for the physical ailments, but also for the spiritual condition of his parishoner.

This condition of things gradually passed away, until to-day, payment is demanded and expected.

The Amount of the Fee.—*General Practice.*—The average office fee in cities is two dollars for advice only, and more if any special service is required. House calls vary from three to five dollars—for accouchment, from twenty-five dollars upward according to the circumstances of the family, and the nature of the case.

For minor surgical operations done by the family physician, such as circumcision, removal of adenoids, amputation of tonsils, and the like, twenty-five to fifty dollars. Night calls are charged double the day rate, and according to the distance.

Twenty-five years ago, it was the common practice for the physician in the country to charge for an office call only fifty cents and then frequently give the medicine; at the present time in most places one dollar is charged for the ordinary call at the office.

For calls made at the residence the usual fee is one dollar and fifty cents for within a mile, two dollars for two miles, and so on, in proportion to the distance.

For fractures of the fingers or toes, the reduction, dressings, and other necessary charges, five to ten dollars; for the reduction of a fracture of any of the long bones, with dressings, twenty-five dollars. Amputation of the leg or arm, or appendectomy, one hundred to one hundred and fifty dollars is customary.

Operations on the tonsils or the removal of adenoids, twenty to thirty dollars.

In obstetric practice ten to fifteen dollars is charged in ordinary cases, where no instruments are necessary, and twenty-five when they are required.

Many practitioners in the country rely largely on the practice from the summer hotels in their vicinity for the actual money saved during the year, as they charge much larger fees—from three to five dollars a call, the calls are more frequent, as the city patient requires it, the country patient will say, "if we are not better will let you know" thus limiting the number of calls. Many physicians in suburban places and country villages lose much by rendering bills once or twice a year only—making their bills out from daily memoranda, carelessly made at the time, so that they are often indirect as to the debtor. It is better to render bills monthly and thus educate the people to prompt payments.

Specialists.—The usual office fee for the first visit is ten dollars, and five dollars for subsequent ones. In gynecological cases that require more time for the examination, frequently, twenty-five dollars is the first fee.

When the patient is brought to the consultant's office by the family physician the first fee is usually twenty-five dollars, as more time is consumed in telling the patient as well as the physician.

It is the custom in many offices to allow not more than twenty minutes to any one case, and if sufficient facts are not discovered to make a proper diagnosis, another visit is expected, the second fee being less than the first. There are some rare exceptions where the general fee is twenty-five dollars, for each visit.

Then again for special work, like the treatment by radium or the making of skiagraphs, and the like, charges are made according to the time consumed.

Consultants.—It is the general custom in New York and other large cities, to charge ten dollars an hour from the time of leaving the office, until the return to the same, and to charge additionally for the service rendered at the place of consultation; if there is an operation, according to its importance, and if only advice is given, according to its benefit to the patient. Occasionally the fee is agreed upon beforehand—a practice that is much to be preferred, as there can then be no misunderstanding or dispute.

Operative Surgery.—Fees in operative cases vary according to the locality, but the variations are greater than for medical service.

Many medical societies have made schedules, but they are never lived up to, and it is foolish to have any such; each case should be determined separately, according to the circumstances of the patient, and the benefit conferred.

Accident insurance companies have adopted a table, and in many of the courts their schedule has been followed. Their rates are, however, too low. The following are some of them:

Appendectomy	$100.00
Fixation of kidney	100.00
Laryngotomy	50.00
Rectal operations	25.00
Mastoiditis	50.00
Extirpation of malignant tumor	50.00
Amputation of the thigh	100.00
Reduction of dislocation of the shoulder, elbow, hip, or knee	25.00
Excision of the shoulder, hip, or knee	100.00
Reduction of fractured thigh	75.00
Knee cap	50.00
Fibula or tibia	50.00
Radical treatment of hernia	100.00

The following is a partial list of fees allowed by the New Jersey Medical Society, at a meeting held at New Brunswick, July 23, 1766.

Phlebotomy	1s. 6d.
Extracting a tooth	1s. 6d.
Incised or contused wounds of large size, dressings, and ointments	7s. 6d.
Operation of the trepan	£3.
Cataract extraction	£3.
Delivering a woman in a natural case	£1.10s.

These fees are in the "Pine tree Shillings," and the proclamation money pound was equal to one-fourth less then the English pound.

Large Fees.—Many tales of large fees have been reported from time to time but most are not authentic. After carefully looking over the field, and examining thoroughly the subject, I find that the highest fee ever paid in the United States was for an appendectomy, done upon a very wealthy person; the sum paid the surgeon was 25,000 dollars. A surgeon in New York received from a patient upon whom he had made a mastoid operation 10,000 dollars, and another surgeon for the same operation received 14,000 dollars.

A NewYork surgeon was asked to go out of the city some 100 miles to examine and pass upon the surgical dressings of a patient who had received an injury to the thigh, the dressings having been applied by the family physician. The patient was wealthy, the dressings were found to be correct, and so pronounced by the consulting surgeon; the fee charged was 10,000 dollars, and was paid. Fees for appendectomy are quite common at 1,000 dollars, and the same amount is frequently paid for fixation of the kidney.

Many operators will not undertake a laparotomy for less than 500 dollars, and in many instances where the operation is performed in a hospital payment of the fee is demanded in advance, not that the surgeon personally asks for it, but the patient is told that the rules of the institution require it.

For cataract extraction we have known of 2,000 dollars being paid, and the same amount for double iridectomy for glaucoma.

The Law In Relation To Fees.—Under the Roman and Civil law, and formerly in England the services of a physician to his patient were in legal contemplation honorific, like those of an advocate or barrister. An action for fees could not be maintained by a physician on an implied contract as might be done by a surgeon or an apothecary. But since the passage of the Medical Act, anyone registered thereunder can recover.

It sometimes happens that a patient dies leaving his physician unpaid, and the executors refuse to pay; and then where the plantiff is forbidden, as in New York (Code of Civil procedure, p. 829, Ross. *vs.* Ross, 6 Han, 182) to testify in his own behalf, unless the executor so testify in behalf of the estate, proof of the services must be made otherwise than by the physician's testimony.

In the United States no distinction is made between the laboring man working with his hands and the man working with his brains as to payment for his work. The honorarium is not known in this country, and the physician's right to payment is based on a contract expressed or implied. There may be an express agreement as to amount of compensation, and also as to the person or persons responsible for the same; but this is seldom the case and the contract is usually implied, the amount of the fee being that usual in the vicinity. Failure to cure the patient is no bar to the action, as no guarantee is given.

A asks a physician to attend B, and says, "I will pay" or "I will see you paid," A is liable and the physician may recover. A asks a physician to treat B, and says, "if B does not pay you I will"; if this is not in writing the physician cannot recover from A. Again, A says to a physician, after services have been rendered to B, "I will pay"; A is not liable.

In the first case, it is an ordinary contract and does not come under the Statute of Frauds, because it is an individual promise; the next case is covered by the Statute of Frauds; in the last case, there is no consideration upon which to make a contract, and therefore whether written or oral there is no legal promise.

Consultant's Fees.—In the case of a consultation, the custom seems so well established, that the patient will pay the fee of the consultant, that an agreement between the patient and the attending physician, that the physician will pay the consultant's fee does not relieve the patient from paying such fees, unless the consultant is informed of such arrangement before the services are rendered (Shelton *vs.* Johnson, 40 Ia. 84).

Collections from Estates of Decedents.—The claim against a decedent's estate must be filed or presented by the person who owns it or has an interest in it, with the right of enforcing collection, or by his lawfully authorized agent; the amount of the claim should be verified by affidavit, setting forth that the physician is regularly registered, that he treated the decedent, that the amount due is —— dollars, that no part of it has been paid, and that it is now due and payable.

At common law the expenses for the "last sickness" came sixth on the list of items. In the United States the following is the order: first, funeral expenses; second, expenses of administration; third, expenses of last sickness. This classification is generally recognized in most of the States, but is not universal. The latter include the fees of the attending physician and of the attending nurse, and the cost of medicines. What the term "last sickness" means is a question not free from doubt, as see the following: In "Louisiana, (Succession of Whittaker 7 Rob. (La.) 91) the plaintiff physician lost his case, as the statute said "last sickness." In this case the patient had an incurable disease for which the physician treated him, trying to alleviate his suffering; the immediate cause of death was a pistol wound. The code specified that the "last sickness" is considered to be that of which the debtor died," thus defeating the claimant's preference.

A physician's charge for services may be properly based on the patient's ability to pay, and it has been legally affirmed that one thousand dollars is a reasonable fee for performing the operation of gastrotomy on one whose estate was inventoried at $8,705. The lower court gave a verdict for the physician of $500; on appeal the higher court gave the above decision. (Czarnowski *vs.* Zeyer, 35 La.)

Responsibility for Payment.—A parent is bound to pay for medical services given to his minor children; after majority, unless some special order is given, the parent is no more responsible than a stranger, A husband is liable for the medical bills of his wife. even though he is not living with her at the time.

If the master calls a physician to treat a servant he is responsible, even though he makes no direct promise to pay. If the master's wife calls the physician in such a case, the master is not responsible, even though his wife has promised to pay the bill. If it can be shown, however, that the person calling the physician is acting as an agent, then the principal will be liable.

In treating an employe of a corporation the physician should be careful to obtain the authority of the proper officer, generally the president or some other member of the Board of Directors.

Division of Fees.—This abuse and violation of ethics was known, or believed to exist for several years before any action against it was taken by the medical authorities. The matter was first taken up by the Erie County (N. Y.) Medical Society which condemned the practice, and later by the New York Academy of Medicine which passed resolutions in condemnation of the secret division of fees and voted that any member of the society proved to be guilty of this practice should be expelled. Many State medical societies have framed similar resolutions.

The legal aspects of fee-splitting have been very recently decided in Michigan as follows: McNair *vs.* Parr (Mich.) 143 N. W. R; 42. In this case the Supreme Court of Michigan reverses a judgment recovered by the plaintiff for professional services for operations performed on the family of the defendant, and grants a new trial. The court says that the defendant claims among other things, that at the time the causes of action arose there existed between the plaintiff and Dr. S., who was then the defendant's physician, an unlawful agreement and combination, by which the plaintiff and Dr. S. were to divide the fee which the defendant was to pay the plaintiff for the operations and professional visits mentioned in the plaintiff's bill of particulars, which combination was unlawful and void, as contrary to public policy, and in violation of the statutes and common law of the State. The court held that any agreement of the plaintiff to split his fees with Dr. S. without the knowledge of the defendant would be void as against public policy. William Oliver Moore.

Fel Bovis.—Ox-gall.—"The fresh bile of *Bos Taurus* L." (U. S. P.).

A brownish-green or dark green, somewhat viscid liquid, having a peculiar, unpleasant odor, and a disagreeable, bitter taste. Specific gravity: 1.015 to 1.025 at 25° C. (77° F.). It is neutral, or has a faintly alkaline reaction on litmus paper.

A mixture of two drops of ox-gall and 10 c.c. of water, when treated, first, wih a drop of a freshly prepared solution of one part of sugar in four parts of water, and

afterward with sulphuric acid, cautiously added, until the precipitate first formed is redissolved, gradually acquires a brownish-red color, changing, successively, to carmine, purple, and violet.

Purified Ox-gall, Fel Bovis Purificatum (U. S. P.).—Fresh ox-gall, 300 c.c.; alcohol, 100 c.c. Evaporate the ox-gall, in a tared porcelain capsule, on a water bath, to about *one hundred* (100) *grams*, then add to it the alcohol, mix the whole thoroughly, and set it aside, well covered, for three or four days. Then decant the clear solution, filter the remainder, and, having mixed the liquids and distilled off the alcohol, evaporate the remainder to a pilular consistence.

A yellowish-green, soft solid, having a peculiar odor, and a partly sweet and partly bitter taste. Very soluble in water and in alcohol.

A solution of 1 part of purified ox-gall in about 100 parts of water behaves toward sugar and sulphuric acid in the same manner as the solution mentioned above. An aqueous solution of purified ox-gall should be clear, and should remain transparent upon the addition of an equal volume of alcohol (evidence of proper purification).

This complex substance in its crude condition consists of about ten per cent. of solids and ninety of water. The most important solid contituents are about three per cent. of the *sodium salts* of *taurocholic* and *glycocholic acids*, and several not very well distinguished coloring matters (*bilirubin*, *biliverdin*, etc.). Besides these it also contains a number of decomposition products, *cholesterin*, *urea*, etc., and some *fats* and *mucus*. Further than to show its practical identity with that of the human subject, the study of the specific composition of ox-gall is unimportant.

For the same reason the study of its action pertains wholly to physiology. We know that bile has no business in the stomach, although it appears that its entrance there, in certain morbid conditions, may exert a stomachic effect, without seriously inhibiting digestion, and its therapeutic use may be serviceable in this way. It must, however, be remembered that the properties of the bile itself are subject to change in the stomach, so that suitable measures must be taken in its administration (see below), when the intestinal action is desired.

It is equally well established that bile in the circulation acts as a poison, although there are some facts to suggest that its antitoxic action there may at times more than counterbalance such objection.

It is then in the intestine and in the liver that we must look for the beneficial effects of the administration of bile. In the former it is a valuable antiseptic, peristaltic stimulant, chemical synergist of certain purgatives, and promoter of the absorption of fat. None of these processes requires discussion. All can be effected by ox-gall, properly administered, as by the natural secretion. Upon the liver, the drug has the effect of a direct cholagogue, that is an agent increasing the actual secretion of bile. Since the constituents of the bile decomposed in the intestine are returned to the liver to be again combined, we should naturally expect this increase to be produced. It appears, however, that the increase is greater than the ratio thus accounted for, and it is apparent that the bile salts exert a stimulating effect upon the secreting mechanism.

The action of ox-gall in assisting the absorption of fats and oils, and its aid in maintaining intestinal antisepsis, has suggested its use as a proper means of treating typhoid fever and some favorable reports of such treatment have been published.

It has been very properly pointed out that the enclosing of the dose in *keratin* tends to prevent changes in it by the acid gastric juice, in its passage through the stomach.

Its injection into the rectum, in twenty-grain doses well diluted, tends to clear that organ of feces.

Recently, the use of the bile salts, in five-grain doses, has largely superseded that of the bile.

HENRY H. RUSBY.

Fennel.—See *Foeniculum*.

Fenugreek.—FENUM GRAECUM. The seeds of *Trigonella foenum-graecum* L. fam. *Leguminosae*, a very ancient food and drug of India, produced upon a cultivated and wild erect, branching herb. The seeds are about one-eighth inch long and nearly as broad, and a little more than half as thick. They are irregularly rhomboidal, with rounded edges, and grooved diagonally, on both sides. They are of a peculiar brownish-yellow, sometimes grayish-yellow color, smooth, peculiarly and not very pleasantly odorous, and of similar fatty and bitter taste. About one-fourth of their weight is gum, nearly as much albumin, and there is seven per cent. of ash, with six of a disagreeably smelling and tasting fatty oil and a little resin. There are small amounts of *choline* and *trigonelline* ($C_7H_7NO_2+H_2O$). They are largely eaten as an albuminous food and are also regarded as tonic (doubtless due to the bitter alkaloid) and carminative. They are also very largely used in the ground state for poultices. The absorbable properties of the alkaloid, so applied, are unknown. They are very largely used as food and medicine for cattle, and this is almost their exclusive use in this country. The very young herbage is similarly used as a sort of *medicinal food*, much as are dock leaves and dandelion leaves.

HENRY H. RUSBY.

Ferguson, Alexander Hugh.—Born February 27, 1853, in a small village in Victoria County, Ontario. He was graduated with honors from the Medical Department of Trinity University, Toronto, in 1881, and after post-graduate study in New York and Europe began the practice of his profession in Winnipeg, Manitoba. He was professor of physiology and histology from 1883–1886 and professor of surgery from 1886–1894 in the Manitoba Medical College and during this time served a term as president of the Manitoba Branch of the British Medical Association. In 1894 Dr. Ferguson removed to Chicago where he was appointed professor of surgery in the Chicago Post-Graduate Medical School, and later occupied the chair of clinical surgery in the Medical Department of the University of Illinois. He was soon recognized as a surgeon of the first rank and rapidly acquired fame and a wide clientele. He died October 20, 1911, from septicemia following a carbuncle.

Ferguson was a man of wide reading and was also a frequent contributor to medical literature, over forty articles from his pen appearing in various medical journals from 1890 to 1911. He contributed the article on Diseases of the Urinary Bladder and Prostate in the American Practice of Surgery, and was the author of "The Technique of Modern Operations for Hernia," 1908.

T. L. S.

Fergusson, Sir William.—Born at Preston Pans, Scotland, March 20, 1808. At the age of fifteen, according to his own wishes, he was placed in a lawyer's office. After two years of work he abandoned the law to study medicine, entering the medical profession in 1825. All through his medical course he showed a wonderful talent for surgery and love for anatomy, becoming one of the favorite pupils of Dr. Robert Knox. In 1826 he was appointed assistant to John Turner, Professor of Surgery in the University of Edinburgh, and in 1828 secured the post of Demonstrator of Anatomy to a class numbering four hundred. During the same year he became a Licentiate of the Royal College of Surgeons of Edinburgh, and in 1829,

when but twenty-one years of age, obtained his Fellowship of that College by examination. In 1831 he was elected Surgeon to the Edinburgh Royal Dispensary, and made this one of his brilliant periods of work by performing, among other operations, the tying of the subclavian artery, an operation which had been performed but twice before in Scotland. In 1835 he accepted the Chair of Surgery at University College Hospital in London. In 1839 he was recalled to Edinburgh to become Surgeon to the Infirmary and a little later he became a Fellow of the Royal Society of Edinburgh. In 1840, however, he was again called to London on his election to the Chair of Surgery at

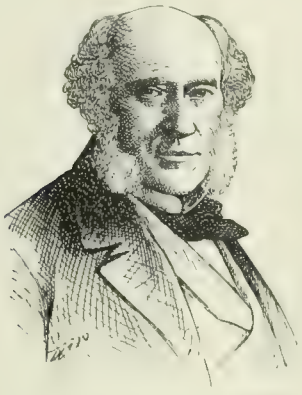

Fig. 2371.—Sir William Fergusson.

King's College and Surgeon to the Hospital, which at this time was established in connection with the College. In 1849 he was appointed Surgeon-in-Ordinary to H. R. H. the Prince Consort, and in 1855 he became Surgeon Extraordinary. In 1867 he was made Serjeant Surgeon to the Queen. He became a member of the Court of Examiners in 1867 and President of the College in 1870. As Professor of Human Anatomy and Surgery he delivered two courses of lectures in 1864–65, which were afterward published under the title of "The Progress of Anatomy and Surgery in the Nineteenth Century." In 1866 he was created a baronet. During the last years of his life he was Clinical Professor of Surgery and Senior Surgeon to King's College and Hospital, also a Fellow of the Royal Society of Great Britain, and a member of most of the learned societies of Europe. His death occurred on February 10, 1877.

Sir William Fergusson, while successful as a teacher, was chiefly famed for his skill as an operator. The operations for which he was best known were those for cleft-palate, harelip, excisions of joints, removal of the maxilla (called Fergusson's operation), and amputations. He did not contribute a great deal to medical literature and his one work, mentioned above, is the best known of his writings. E. L. J.

Fermentation.—By the term fermentation is usually meant alcoholic fermentation, that is the formation of alcohol from sugar through the medium of yeast cells. Of the various views concerning the nature of the processes concerned in fermentation may be mentioned that of Liebig and that of Pasteur. According to the former fermentation was brought about by yeast through the presence of ferments which were capable of effecting the changes characteristic of fermentation by their mere presence, or by what was described as a catalytic action. Pasteur, on the other hand, held that alcoholic fermentation is a consequence of the life of the yeast organism in contact with sugar and away from the air. The cell, according to this view, must be supplied with a sufficiency of oxygen and this, under the fermenting conditions, it takes from the sugar, giving off carbon dioxide as an oxidation product and producing alcohol at the same time, in consequence of the cleavage of the sugar molecule. Looked at from the standpoint of Pasteur, fermentation is to be regarded as a purely biological process with alcohol and carbon dioxide as excretory and respiratory products respectively. The theory of Pasteur gradually supplanted that of Liebig in spite of the fact that the former idea did not explain adequately all the facts known concerning the process. In line with this theory a similar explanation was offered for the action taking place in the formation of acetic acid, lactic acid, and butyric acid.

Although the work of Pasteur gave an enormous impetus to the study of the common fermentations it is evident that the biological explanation for this process was valueless in accounting for the changes produced by the active agents described as pepsin, trypsin, diastase, etc. To avoid confusion it became customary to speak of organized and unorganized ferments, or of insoluble ferments, such as yeast, and soluble ferments, such as pepsin, etc. In time soluble ferments became known as enzymes.

A certain degree of skepticism among various scientists toward the theory of Pasteur manifested itself from time to time and gradually the idea was evolved that the so-called organized ferments, or living cells, are capable of producing the changes characteristic for fermentation because they secrete soluble ferments, or enzymes. Repeated efforts to prove the correctness of such a view failed until in 1897 Buchner succeeded in isolating from yeast cells an enzyme capable of carrying through the processes of fermentation in every respect identical with the entire yeast organism. This body was called zymase. Since its isolation the view that there is a difference in action of organized ferments and unorganized ferments has been done away with and at the present time all fermentation processes are ascribed to the presence in living cells of enzymes. See *Enzymes*.

Frank P. Underhill.

Ferments.—See *Enzymes*.

Ferments, Metallic.—Before entering in a discussion of our subject proper it will be necessary to describe the character of colloids. Thomas Graham distinguished first between crystalloid and colloid substances, the former when in solution being easily diffusible, the latter not being able to diffuse through membranes. This original definition of colloids has been given up in recent years. The diffusibility of colloids varies within wide limits, although they diffuse with greater difficulty than the crystalloid substances of Graham. Furthermore, we now know of typical colloids which, under certain conditions, can be made to crystallize and, reversely, P. von Weimarn could show that chemical reactions between concentrated solutions of salts (crystalloids) lead often to the formation of gelatinous (colloid) substances; it is even probable that certain gelatinous (colloid) substances consist of aggregations of minute crystals (P. von Weimarn, R. Zsigmondy). The size of the particles of a certain substance suspended in a liquid determines whether or not it is to be considered a colloid. If the size of these particles is so large that it changes the physical properties of the mixture (system) in a definite manner, we have to deal with a colloid. There exists one continuous transition between the coarse suspensions, where the colloid particles can easily be recognized with the naked eye or the ordinary microscope, to colloidal solutions, where an ultramicroscope or other physical means are required for the detection of the colloid ("disperse") particles suspended in a fluid and to the homogeneous solutions in which the dissolved particles are the ordinary molecules.

The transition is so gradual that sharp lines of demarcation cannot be drawn; thus the molecules of dextrin and even of sugar when dissolved in water have already some of the characteristics of colloids. H. Siedentopf and R. Zsigmondy called particles still visible through the ordinary microscope *microns* (for instance particles of mastix or kaolin). Particles smaller than 0.1μ and larger than 1$\mu\mu$ which could be recognized in the ultramicroscope were called *submicrones* (many particles of colloid solutions of metals); particles smaller than 1 $\mu\mu$ can no longer be recognized through the ultramicroscope (*amicrones*), for instance, the smallest particles of electrically prepared solutions of metals, molecules of starch, dextrin.

This variation in the size of the particles on which the difference between ordinary homogeneous and colloid (disperse) solutions depends, leads to a corresponding difference in certain physical or physicochemical characters between these two kinds of solutions. (1) Colloids in solution diffuse much more slowly into the surrounding fluid of the same character as the one in which they are suspended than substances which form with the same fluid a homogeneous fluid; the former penetrate therefore also more slowly into gelatin or agar than the so-called crystalloids (molecular disperse) substances. The rapidity of diffusion varies, however, between different kinds of colloids. (2) Colloids filter much more slowly through parchment or collodion than crystalloids. By varying the character of the filters and using a certain pressure Bechhold was able to separate different colloids suspended in the same fluid and to determine approximately the size of the colloid particles (ultrafiltration). (3) If a beam of light is passed through a solution, light will be given off by the colloid particles in all directions and the solution appears opalescent; furthermore, the laterally emitted light rays are partly polarized (phenomenon of Tyndall). If the particles are very small, and a specific refraction and absorption of the light rays through the colloid particles does not take place, the color of the scattered light is blue. If the small particles cause a specific refraction or absorption of light rays, the solution may appear in various colors, a condition which is especially noticeable in the case of colloid solutions of certain metals.

In the ultramicroscope colloid particles, against which a beam of light is directed, are observed with strong lenses. Here the submicrones show Brownian movements, while the still smaller amikrones merely cause a diffuse opalescence.

In accordance with the large size and proportionately small number of suspended particles in a colloid solution only a very slight lowering of the freezing or raising of the boiling point takes place and in some solutions freed from adhering electrolytes this change seems to be almost nil. Colloids exert also a certain osmotic pressure; this osmotic pressure is, however, relatively low in pure solution and is dependent upon a larger number of variables than in the case of electrolytes. Mechanical factors, age of solution, addition of electrolytes influence the osmotic pressure in a manner which differs in the case of various colloids. The osmotic pressure, furthermore does not depend only on the number of colloid particles but also on the size and character of the particles.

A colloid solution in which the dispers particles are of the size of submicrones is called a "sol." If the colloid particles in a sol become massed together so that they form more or less a continuous mass more distinctly separated from the fluid in which they were formerly more equally distributed, they have been transformed into a "gel" (through precipitation, coagulation, gelatinization of the sol).

We may divide the colloids into two classes: (1) the suspension colloids or suspensoids, and (2) the emulsion colloids or emulsoids. In the former the disperse particles are solid, are sharply demarcated from the fluid in which they are suspended; they are therefore said to be "lyophobe." In the latter the particles are more or less liquid, they exert a certain attraction on the fluid in which they are included, and take up a certain quantity of this fluid; they are "lyophil." Examples of the former class are the colloid solutions of metals, certain sulphides (As_2S_3, Sb_2S_3), and metal hydroxides in diluted solutions, although the latter in concentrated solution may belong to the second class; certain stains like congo red are also suspensoids, while other stains have rather the character of emulsoids. To the second class belong especially those colloid substances which constitute a great part of living organisms (proteins, gelatin, agar, various lipoids). In the emulsion colloids the gradual transition between the disperse particles and the surrounding liquid causes the solution to be viscous, while the suspension colloids produce only a very slight viscosity. In suspensoids the particles have about the same surface tension as the fluid in which they are suspended, while in colloid solutions of emulsoids the surface tension of fluid (especially water) in which they are suspended has been lowered The suspension colloids can be readily precipitated through the addition of electrolytes, and this precipitation remains unchanged, after removal of the electrolytes—the precipitation being irreversible—while the emulsion colloids are usually very much less sensitive to the addition of electrolytes and if coagulation takes place, it is generally a reversible condition, removal of the electrolytes leading to a return into the state of colloid solution.

The suspension colloids in a liquid have an electric charge. The metal hydrates are usually positively charged and migrate therefore in an electric current toward the cathode, while the majority of the other suspension colloids have a negative charge and migrate to the anode; this holds good especially in the case of the electrically prepared colloid metals. The charge depends to some extent upon the chemical character of the suspension colloid, in part, however, it depends upon adsorption of certain ions which are present in the fluid surrounding the colloid particles. While each particle of a suspension colloid is usually a mechanical aggregate of chemically relatively simple molecules, the emulsion colloids are in many cases very large single molecules the size of which determines the colloid character. Each particle may here also consist of aggregates of molecules. The proteins are typical emulsion colloids. They are also usually electrically active; this electric activity is however very weak, if the protein has been freed as much as possible through dialysis from adhering electrolytes. Proteins dissociate H as well as OH ions, they are therefore amphoteric; their acid is, however, somewhat greater than their alkaline dissociation constant, and they migrate therefore slightly more to the anode than to the cathode. If we add acid to the suspension or emulsion colloid both take on a positive charge and migrate to the cathode; the reverse takes place if we add alkali to the solution. The mechanism, however, through which the electric charge is influenced in the case of suspension colloids and of proteins is somewhat different; in the former it depends upon adsorption of H or OH ions, while in the case of proteins the addition of alkali or acid changes the acid and alkali dissociation constant of the molecule.

We stated above that the readiness with which suspension colloids are precipitated through small quantities of electrolytes is very characteristic. Some very interesting rules determine the efficacy of various electrolytes in precipitating suspension colloids. They may be summarized as follows: (1) Electrically positive colloids are principally precipitated by anions (ions with negative charge), electrically negative colloids are precipitated by cations (Hardy). (2) The greater the valency (number of electric charges) of ions, the greater is their precipitating power. (3) In addition there may be, in the case of

certain ions, other factors of importance such as their solution tension (their tendency to pass from an electrode into a solution, to become ionized, electrically charged); the greater the solution tension, the smaller is the precipitating power of the substances. It is also probable that the mobility of the ions is of importance, very rapidly moving ions as H and OH being especially active.

There is a marked parallelism between the precipitating power which electrolytes exert on colloids and their adsorption by the colloid particles. For instance, bivalent cations which have a greater precipitating power than monovalent cations are more readily adsorbed.

Suspension colloids are precipitated not only through addition of electrolytes but also under the influence of other colloids, provided the two colloids have the opposite electric charge and are mixed in proportions which permit the approximate, at least temporary, neutralization of the electric charges of the two colloids. The electric charge is also of importance in the interaction between electrolytes and colloids. If the colloid particles are negatively charged the cation of the electrolyte is mainly concerned in the precipitation of the colloid, while a positively charged colloid is principally acted upon by the anion.

Furthermore, it has been found that the suspension colloids are the least stable the nearer they are to the isoelectric point, and the smaller is their electric charge, and correspondingly their tendency is to move in an electric field toward an electrode. All these facts suggest that the precipitation is intimately connected with a neutralization of the electric charge of the colloid particle through either an electrolyte or a colloid of opposite electric charge; we must assume that the carriers of the opposite charges unite in the moment preceding the precipitation. At present it is not possible to explain in a thoroughly satisfactory manner how the neutralization of the charge leads to the precipitation. We know that the electric neutralization leads to a diminution in the Brownian movement of the colloid particle. Bredig suggested that the increase in surface tension concomitant with the lowering of the electric potential at the surface of the colloid particles caused several particles to unite. Freundlich suggested that temporary differences in the electric potentials of the particles which precede the electric neutralization lead to their mutual attraction and union.

The precipitation of suspension colloids is, as we stated previously, usually an irreversible process; a removal of the precipitating substance from the solution does not lead to the reëstablishment of the colloid solution, and the precipitate remains unaltered. The emulsion colloids, on the other hand, can under certain conditions be brought back to their original soluble state after a precipitation by alkali salts; not, however, after precipitation by salts of heavy metals. The process of precipitation is on the whole more complicated in the case of the emulsion colloids and especially of the proteins. All those substances which increase the ionization of the proteins, increase their viscosity and tend to keep them in the soluble state. Especially alkali and acid in a certain quantity have such an ionizing tendency. Neutral salts, on the other hand, usually diminish the ionization and make the colloid particles electrically neutral; they produce therefore coagulation or gelatinization. Heat and alcohol also cause coagulation of colloid particles. Under the influence of these agencies emulsoids (especially proteins) assume more or less the character of suspension colloids and the addition of small quantities of electrolytes leads now, as in the case of suspension colloids, to an irreversible precipitation.

While in the case of suspension colloids, particles with opposite electric charges precipitate each other, emulsion colloids, as, for instance, solutions of proteins, may be precipitated by suspension colloids of the opposite as well as of the same electric charge; this corresponds to the readiness with which proteins are adsorbed by positively as well as negatively charged suspended particles.

Fats and oils can be easily emulsified in water after the addition of a little alkali. Such emulsions are somewhat more stable than the suspension colloids. Lecithin can be readily emulsified with water; this emulsion resembles in its reactions lyophile (hydrophile) colloids. Cholesterin behaves more like a suspension colloid and is readily precipitated by certain electrolytes as well as by certain colloids. Both cholesterin and lecithin behave as anodic (electronegative) colloids.

Coarse suspensions (for instance charcoal, kaolin, mastix, bacteria, red blood corpuscles) are precipitated on the whole under similar conditions as colloidal solutions. In most cases the suspended particles are electronegative and they are therefore precipitated by positive ions, in some cases, however, more readily than in others; suspensions of bacteria, for instance, behave like suspension colloids and are easily precipitated by electrolytes only after a previous heating or after they have been acted upon by an agglutinin, which itself represents a hydrophile (emulsoid) colloid.

We mentioned previously that emulsion colloids are more stable than suspension colloids. By adding a certain amount of an emulsion (hydrophile colloid) for instance, gelatin, albumose, dextrin, gum arabic, it is possible to make suspension colloids, especially the ordinarily unstable hydrosols of metals, much more stable; the emulsion colloids assume under those conditions to a great extent the properties of a protective colloid which, as we may assume, forms a coat around the individual particles of the suspension colloid. The two colloids must, however, be added in such proportions that the opposite process, namely, a precipitation, which as we saw may take place under certain conditions if two colloids are mixed, is prevented. Suspension colloids which are manufactured for therapeutic purposes (like collargol) contain always an admixture of a protective emulsion colloid. In a similar manner do alcoholic solutions of lecithin protect albumoses against the coagulating action of alcohol.

On several occasions we referred to the importance which electrolytes have in determining the state of dispersion of the colloids. It has been found that anions as well as cations can be arranged in a certain order according to the strength with which they influence the precipitation or solution of colloids, the taking up of water by gelatine and so on. The order of cations is approximately as follows: Li–Na–K–Rb–Cs. The anions can be arranged as follows: SO_4–Cl–Br–NO_3–I–SCN. It depends in some cases upon the electric charge of the colloid, whether the first or the last ion exerts the strongest action. Similar arrangements of the ions in accordance with their strength of action are found if we examine their influence on the viscosity and surface tension of water, on their catalytic acceleration of certain chemical reactions. A further characteristic of colloid solutions or of gels is the gradual, apparently spontaneous change which they undergo in time. The state and reactions of a colloid depend, therefore also on its previous history, especially on its age. On the whole there exists a tendency for the solutions to become in time less disperse, the smaller particles uniting to form larger aggregates; in gels the density of the more disperse phase may become greater. In certain suspension colloids, however, the opposite effect may occasionally be observed, namely a greater dispersion (decrease in size) of the colloid particles.

Colloid solutions consist of small particles suspended in a liquid. Each colloid particle is separated from the surrounding liquid by a surface. Considering the

small volume of the colloid particles the surface is relatively large; the smaller the particles, the greater is the relative size of the surfaces. These surfaces tend to withdraw from the surrounding liquid certain substances which are dissolved and to keep those substances fixed to the suspended particles. We call this process adsorption. If we call X the quantity adsorbed by one gram of colloid substance and C the quantity of the substance which remains dissolved in the liquid phase, the relative quantity adsorbed is expressed by the following equation: $\frac{X}{C^{\frac{1}{n}}} = K.$

n and K are constants, $\frac{1}{n}$ is always smaller than 1. From this equation we may conclude that relatively more substance is adsorbed from diluted than from concentrated solutions. Not all dissolved substances are equally well adsorbed; those substances are especially adsorbed which lower the tension of surface between the suspended particle and the surrounding fluid. A majority of biologically important substances (proteins, enzymes, soaps) do actually lower the surface tension and are therefore readily adsorbed. In other cases, however, the difference in the electrochemical potential between adsorbing and dissolved substance plays a considerable rôle, as, for instance, in the case of the adsorption of certain dyes. If the adsorbing surface is positively charged, only negatively charged ions are adsorbed and *vice versa*.

These processes of adsorption are of great significance in the living organism. The relatively great surface of the particles enables certain suspension colloids, especially electrically prepared platinum, to act as catalyzers, and in many important particulars these colloid catalyzers behave like the special organic catalyzers which are produced in the living cells, namely the ferments (G. Bredig). Catalyzers are substances which greatly accelerate the velocity of a chemical reaction without changing the end products of the reaction and without themselves undergoing necessarily any permanent change during the chemical reaction. Without the addition of the catalyzer the reaction would follow the same course, but much more slowly. A typical example is the acceleration of the inversion of cane sugar into levulose and dextrose under the influence of acid. The acid is found unchanged at the end of the reaction. There exist, on the other hand, some substances which retard certain chemical reactions; they are called negative catalyzers. If the catalyzer can be readily mixed with the different reacting substances, so that all units of the mixture are homogeneous, we have to deal with a homogeneous catalysis, if they cannot be readily homogeneously mixed, there exist several "phases" and we have to deal with a heterogeneous catalysis. Catalyzers can accelerate various chemical reactions, as for instance oxidations, reductions, hydrolytic splitting of carbohydrates and esters, polymerization, various syntheses. In many reactions ions act as catalyzers, and the catalyzer is effective proportionately to the degree of ionization of the catalyzing substance.

The catalyzers undergo in many cases a union with the reacting substance. The union is only a temporary one and the catalyzer is restored to its original condition before the reaction is completed. These intermediary substances produced with the aid of the catalyzer are more labile than the original substance, and thus under certain conditions an acceleration of the reaction can be produced through the addition of a catalyzer. It was known previously that platinum black and similar substances can accelerate certain chemical reactions. Also other solid substances can accelerate certain reactions. For instance, the production of H_2O from H and O is accelerated through the surface of the porcelain dish and is proportionate to the size of this surface.

There is present a certain degree of specificity in the action of inorganic catalyzers and furthermore the catalyzers are often partly destroyed during the principal reaction as a result of secondary reactions taking place. In most respects these inorganic catalyzers resemble therefore the ferments which are of such significance in the processes taking place in the living organisms. The latter consist mainly of colloidal substances (emulsion colloids) and it is therefore of the greatest interest to know that also suspension colloids, especially colloidal metals, can act as catalyzers and that there exist far-going similarities in the action of these colloidal metals and of ferments. We owe mainly to Bredig and his pupils the analysis of these similarities.

Bredig showed that colloidal solutions of many heavy metals can be produced by letting a constant electric current pass through carefully prepared distilled water, so that a spark penetrates through the water. Under these conditions small particles of the metal are torn off from the cathode and these particles are suspended in the water. Bredig showed furthermore that these colloidal (rather unstable) solutions can act as catalyzers accelerating various chemical reactions; he analyzed especially the decomposition of H_2O_2 into H_2O+O. In these cases we have to deal with a catalysis in a heterogeneous system, a definite surface separating each colloidal particle from the surrounding liquid which contains the substance which undergoes chemical changes. The rapidity of a catalytic reaction in a heterogeneous system depends to a great extent upon the rapidity with which the substances dissolved in the surrounding fluid diffuse through the fluid to the surface of the catalyzer. At the surface of the colloidal catalyzer the various substances are condensed, their concentration is increased and they undergo therefore certain chemical changes more rapidly than if homogeneously distributed in the fluid. This is supposedly the mechanism through which colloid metals act as catalyzers.

Just as in the case of the catalyzer of the blood, a very small quantity of the metallic catalyzer is sufficient to split a relatively enormous quantity of H_2O_2. Both the reactions under the influence of the catalase and those under the influence of the colloidal metal follow the equations for monomolecular reactions. The temperature coefficient is greater if colloidal solutions of platinum than if sheets of platinum are used as catalyzers and there exists in the case of ferments as well as of colloidal solutions an optimal temperature.

The catalytic action of colloidal solutions of metals is increased if a certain quantity of alkali is added. In a similar manner addition of alkali to some, of acid to other ferments increases their activity. Minimal quantities of such substances as HCN, $HgCl_2$, H_2S paralyse the catalyzing effect of the colloidal solutions of metals as well as of the catalase of the blood and certain other ferments, and in both cases, after some time, a recovery can take place from the effect of certain of these poisons. Both colloidal solutions of metals and ferments are very labile.

There exist therefore marked analogies between ferments (enzymes) of the living cells and colloidal metals. It is even probable that in the case of colloidal solutions of metals intermediary reactions take place between the metal and the H_2O_2 and that the acceleration through the catalyzer depends upon the temporary formation of such intermediary bodies.

It is of great interest that the catalyses effected through mercury are represented by a pulsating curve, short periods of greater and of diminished acceleration alternating; simultaneously can be found pulsating changes in the electric potential of the system, similar to the pulsating differences in the electric potential during the rhythmic activity of the heart; there is furthermore a similar influence of the temperature on the pulsatile catalytic decomposition of H_2O_2 through mercury and on the rhythmic contraction of the heart.

These analogies between the action of enzymes and that of colloidal solutions of metals is certainly of great interest and significance, even if at the present time we may hesitate to admit the essential identity in the mode of action of these two kinds of substances.

These colloidal solutions of metals exert definite effects on the cells *in vitro* as well as in the body. If a certain quantity of an electrically or chemically prepared inorganic colloid is added to autolyzing liver, the autolysis is accelerated provided the (chemically prepared) colloid is not added in too large an amount, in which case it has, on the contrary, an inhibiting effect. Positively as well as negatively charged colloids exert this influence equally well (M. Ascoli and G. Izar).

After intravenous injection of colloidal metals in mammals the output of nitrogen is increased, even if relatively small quantities are given. Colloidal solutions of various metals have the power to oxidize certain substances or they accelerate the action of certain oxidizing ferments.

Colloidal solutions of various metals have a bactericidal action *in vitro*. Their action on different organisms is not equally strong. Colloidal Ag acts strongly on the typhoid and dysentery organisms and is also active on the staphylococcus and anthrax organism, less on the colon bacillus. The degree of the bactericidal efficiency seems to depend on the size of the colloidal particles; the smaller the particles the stronger is the bactericidal effect (V. Henri). *In vivo* also it has been possible to demonstrate the bactericidal effect of colloidal solutions of metals. According to Foa and Aggazzotti it is possible to delay but not to prevent the death of rabbits infected with staphylococci or streptococci through subsequent injections of colloidal metals. After infection with the typhoid bacillus death can be prevented through such injections.

Colloidal solutions of metals have also a certain action on toxins. They destroy *in vitro* staphylolysin (Hamburger). Some other toxins are, however, not affected *in vitro*. *In vivo* it protects rabbits against a dose of tetanus or diphtheria toxin ten times as large as the lethal dose.

After an intravenous injection of a colloidal solution of these metals into a normal organism there follows a rise in temperature (the maximum being reached about three to five hours after the injection) and an increase in the rate of the pulse and respiration. There may be rigor concomitant with the rise in temperature. There is, after a brief transitory diminution, an increase in the number of polynuclear leucocytes. Later there may be noticed a relative increase in the number of lymphocytes. The addition of small quantities of colloidal metals to leucocytes increases their phagocytic power toward certain bacteria and different metals seem to stimulate the phagocytosis of different organisms.

We have observed in patients which had received a long series of injections of colloidal copper, either with or without additional injections of casein, a relative increase in the lymphocytes lasting for many months after the cessation of the injections.

No injurious influence on the kidneys is noticeable, even after injections of large quantities of colloidal copper. In dogs, however, after very great doses of colloidal silver signs of nephritis seem to have been observed.

After intravenous injections of solutions of colloidal metal the presence of the colloidal particles can be demonstrated in the blood and also soon in the bile, pancreatic juice, and urine, but not in the spinal fluid (V. Henri). On sections it is possible to recognize the small particles of metal in the convoluted tubules and in the ascending tubules of Henle in the kidney (A. Mayer and Stodel).

Especially colloidal silver but also colloidal solutions of other heavy metals have been used in the treatment of various acute infectious diseases, as septicemia and pyemia, pneumonia, typhoid fever, and also articular rheumatism. Some results seem to have been obtained in septicemia and pyemia; also in pneumonia the general condition of the patient appears to be beneficially influenced through the injections. A definite influence on the condition of the lungs and the duration of the disease, however, does not seem to be effected through this treatment. In typhoid fever the effect of the injections does not seem to be favorable.

Within the last few years colloidal solutions of metals have been used in the treatment of tumors. The action of various substances on the tumor growth can most advantageously be investigated in the case of the transplantable animal tumors. Here the conditions are much less variable than in the case of human cancers. The writer showed a number of years ago that by subjecting tumors *in vitro* to the action of certain chemicals the energy of their subsequent growth in the body can be diminished in a graded manner. About two years ago von Wassermann discovered that a combination of selenium and eosin injected intravenously into mice causes a retrogression of tumors in a certain number of cases. The curative was very near the lethal dose. Somewhat later Neuberg and Caspari announced that preparations of metals (cobalt, copper, silver, and others) in which the metal would act in a colloidal condition had a similar effect. Neither von Wassermann nor Neuberg stated the chemical character of the preparations they used. We found, in collaboration with Dr. Moyer S. Fleisher, that electrically prepared colloidal solutions of copper and platinum inhibited the growth of transplanted mouse tumors during the period of injection; chemically prepared colloidal solutions of selenium were either inactive or much less active than colloidal copper; while the latter was again much less active than leech extract. Certain proteins as casein and nucleoprotein were also active. Ionized salts of copper, gold, and some other metals were either ineffective or very slightly active. We see then that colloidal solutions of metals have a definite inhibiting effect on the growth of animal tumors and that this effect is a specific one. We found more recently with Moyer S. Fleisher and Miguel Vera that, after a certain number of injections have been given, an immunity against the effect of colloidal copper is established. This immunity has a twofold source. In the first place it is due to certain reactive changes taking place in the organism of the injected animal and in the second place it is due to an immunity acquired by the tumor cells themselves. It is, at least to a certain extent, a specific immunity, inasmuch as immunization against colloidal copper does not protect against the effect of leech extract on the tumor and *vice versa*.

This immunization which takes place very rapidly is a process not only of great theoretical but also of practical interest. It prevents the continued action of the substance on the tumor and permits in many cases the tumor, after a temporary check or partial retrogression, to resume its growth.

Similar processes of immunization seem to take place after continued injection of solution of colloidal copper in cases of human cancer. In human as well as in mouse cancer colloidal copper exerts an inhibiting action on a certain number of tumors. In both cases immunization takes place and after a period of inhibition frequently a new growth of the cancer takes place (McClurg, Sweek, Fleisher, and Loeb).

It remains for us to mention briefly the significance which a study of the colloids has for the analysis of various phenomena of life. The substratum of life consists to a great extent of protein and lipoid substances, which are both colloids. Changes in the state of the colloids will lead to physiological changes in the cells. Thus we find cations and anions to influence various physiological processes (as for in-

stance stimulation of muscle and nerve, hemolysis) in the same order in which they influence the colloid state of emulsion colloids and the taking up of water by gelatin. Entrance of substances into the cells depends to a great extent upon the influence these substances have on protein or lipoid colloids. The solubility of substances in the cell membrane plays a great part in the theory of narcosis (Overton-Meyer) and of artificial parthenogenesis (Jacques Loeb). Similar considerations also hold good in the analysis of edema (Jacques Loeb, Martin Fischer). In this, as well as in all other cases, we have to consider the fact that cells are not directly comparable to homogeneous colloids like gelatin, but that the colloid character of the cell membrane differs from that of the interior of the cell, and that therefore such processes as, for instance, the taking up of water by the living cells are governed by laws that differ from those holding good in the case of gelatin. The colloids of the cell membrane seem furthermore to be of the greatest significance for the oxydation processes in the cells (Jacques Loeb, Warburg).

In the case of the blood cells of *Limulus* the writer could show that the influence of ions on the cell granula and ameboid movements is similar to their action on emulsion colloids and that here again the different ions can be arranged according to their action in the order which we mentioned on previous occasions.

In the formation of stones in the gall-bladder and in the urinary tract the precipitation of colloids plays a great rôle (Schade, Lichtwitz, Bacmeister) and laws which determine the solubility of urates cannot well be understood without a consideration of the colloids of the blood.

The various interactions between antigens and immune bodies are reactions between colloids and it is probable that they represent a combination of adsorption and secondary chemical processes. The specificity of these reactions alone could not very well be explained on the basis of mere adsorption. In the effect of toxins on an organism it is also very probable that processes of adsorption play a great part. Thus in the action of the toxin of heloderma, processes of adsorption can to some extent explain some of the differences in the dose lethal for various classes of animals (M. S. Fleisher and Leo Loeb).

Leo Loeb.

Ferment Test, Aberhalden's.—Aberhalden holds that in the process of digestion and assimilation, the food materials are broken down by the ferments of the gastrointestinal tract into indifferent substances of relatively little complexity which he calls "*Bausteine*." These *Bausteine* (building stones) are taken up by the body and are synthesized into the native materials of the organism. Under normal conditions the process is so regulated that the blood contains only unelaborated material and substances native to the body (*körpereigen*). The process of synthesis involves a number of steps. The blood carries "blood-native" (*bluteigen*) substances which it furnishes to the cell. These are, however, foreign to the cell (*zellfremde*) and must be transformed by the cellular ferments into "cell-native" (*zelleigen*) substances. Only those foods such as glucose and inorganic salts which lack what he calls a specific constitution, are absorbed and assimilated unchanged. An important part of his theory is that the majority of proteolytic ferments are quite highly specific in that they will act only upon certain definite proteins, each ferment having its own protein which alone it is capable of breaking down. The general proteolytic ferments, pepsin and trypsin, of the gastrointestinal tract are greatly in the minority. If now any blood-foreign material finds its way into the blood stream it must be converted into indifferent material, broken down into *Bausteine*, before it can be utilized. For this purpose the body elaborates a specific ferment which will act only upon the substance in question. This action is analogous to the formation of an antibody following the injection of an antigen. Thus bacteria, when they gain entrance to the blood stream, act as specific proteins and stimulate the formation of specific proteolytic ferments which are capable of digesting them, but which are unable to act upon any other proteins. Rather extensive application of Abderhalden's theory has been made in the effort to devise a method for the diagnosis of various conditions. If a serum is incubated with an emulsion of a given bacterium and on examination is then found to contain the products of digestion, there is reason to believe that the serum contains the specific ferment for that bacterial protein, and that the individual from whom it came has been infected with it.

Up to the time of writing this article the test has been used most frequently in the diagnosis of pregnancy. In this condition the placenta, although *körpereigen*, is a specialized tissue and *blutfremde*. From time to time chorionic cells find their way into the blood stream and there stimulate the body to the production of a ferment which is able to digest only placental tissue. The detection of this ferment in the blood of a woman is thus held to be strong evidence that she is pregnant.

In the case of cancer it does not seem always to be necessary for the cell to gain entrance to the blood. The cancer cell is an abnormal one and its metabolism is sufficiently disturbed so that it possibly gives off to the blood *blutfremde* substances which excite specific ferment production. In some other disease conditions it is thought that for unknown reasons ferments are developed against some of the body cells and the result may be dementia præcox, exophthalmic goiter, etc., depending upon what cells are affected.

Two methods have been followed for the detection of this ferment in blood serum, the optic method and the dialysis method. The optic method depends upon the change that takes place in the rotating power of preparations of proteins when acted upon by specific ferments. This method is long and difficult and involves the use of expensive apparatus. It has not been used very much and need not be described. The dialysis method depends upon the fact that proteins do not diffuse through a semi-permeable membrane while the products of protein digestion, peptones and amino acids do diffuse through and can be recognized in the dialysate by means of appropriate tests. This method is also one of some technical difficulty and requires a very strict adherence to the details as described by Abderhalden. Only a brief description can be given here and the reader is referred to the original work for complete directions.

The organ which is to be used, the placenta for example, is obtained in fresh condition, cut into small pieces and washed absolutely free from blood in physiological salt solution and in distilled water. If very fatty it is necessary to extract the material with chloroform. It is then boiled in water containing a little acetic acid and boiled several times in changes of distilled water. This boiling is repeated until the filtrate gives a negative test with ninhydrin. The tissue so prepared is stored in chloroform water under toluol and kept on ice.

Ninhydrin is triketohydrinden hydrate and on boiling with solutions containing peptones or alpha amino acids develops a violet color. It is easier to read than the biuret test and has an additional advantage since the latter does not react to the amino acids. For the semipermeable membrane, Schleicher and Schüll diffusion thimbles No. 579A are selected. It is necessary to test out each thimble before use to prove its impermeability to serum albumin and its permeability to peptone.

Since the blood serum during digestion contains a

variable quantity of diffusible substances which might react to ninhydrin, it is necessary to obtain the specimen after the completion of digestion. It is best drawn directly from the vein into a sterile centrifuge tube. It is centrifuged after coagulation and the clear serum pipetted off into a clean sterile tube. The presence of hemolysis in any degree is said to render the serum unfit for use.

All glassware must be scrupulously clean and sterile. For the performance of the test 20 c.c. of sterile distilled water is placed in each of a sufficient number of small tubes or Erlenmeyer flasks and covered with a layer of toluol. The diffusion shells are washed in distilled water and boiled in water for one-half to one mintue. Five-tenths gram of the prepared albumin is placed in each shell, 1.5 c.c. of serum and a layer of toluol added. The top is carefully closed and the outside washed off with sterile distilled water. The shell is then placed in the tube in such a manner that the portion containing the serum is completely exposed to the water outside. All of the manipulations are to be carried out in such a manner that sterility is preserved. They are then incubated at 37° C. for sixteen hours. At the end of this time 10 c.c. of the dialysate is removed, free from toluol, and boiled for exactly one minute with 0.2 c.c. ninhydrin. The development of a violet color within thirty minutes indicates a positive reaction. There should be ample control of each test using normal and inactivated serum as well as the specimen being investigated. If possible a known positive control should also be employed.

In pregnancy the test has proven very reliable, at least as far as intrauterine pregnancy is concerned. It becomes positive during the second month and disappears within about one month after delivery. In other conditions the results reported thus far are not sufficient grounds on which one might form any conclusions. It has been reported as positive in the majority of carcinomata and in a large percentage of the cases of exophthalmic goiter. In cases of dementia præcox positive results have been obtained with tissue from the cerebral cortex and the ovaries and testicles. The absolute specificity of the reaction is stoutly asserted by some investigators and questioned by others who speak of "group reactions." The ultimate truth will probably be found to lie in some middle ground and the test itself will come to have marked value. RALPH G. STILLMAN.

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Fernel, Jean.—This most celebrated of the French physicians of the sixteenth century was born at Clermont in 1496. He was of a most studious disposition and eager for learning, and his native place not affording what he needed, he went early to Paris, where he gave himself up to a study of mathematics and philosophy. His health soon broke down under the strain and while he was recuperating in the country he became interested in medicine. On returning to Paris he took up this study, supporting himself by teaching philosophy. He began the practice of his profession in 1536. Fernel was a profound student and greatly preferred the science to the art of medicine, avoiding practice as far as he could. But in spite of himself he soon acquired such fame that Henri II wished to appoint him his own physician, but he resisted for a long time under one pretext and another. Finally, however, he was forced to yield and accompanied the

FIG. 2372.—Jean Fernel.

king to the siege of Calais, but soon after his return to Fontainebleau he fell ill from exposure during the inclement winter, and died April 26, 1558.

Among the many works, mathematical, philosophical, and medical, written by Fernel, we may mention the following: "Cosmotheoria," Paris, 1528, in which he suggested measuring one degree of the meridian of the earth, thus foreshadowing the foundation of the metric system of weights and measures; "De Abditis Rerum Causis," Paris, 1548; "Medicina," Paris, 1554, ten editions; "Therapeutices Universales" in seven volumes, Paris, 1554; "De Luis Venereæ Curatione," Antwerp; "Pathologia," Frankfort; "Emissi Sanguinis Observatio." T. L. S.

Fern, Maiden-Hair.—ADIANTUM. *Venus-Hair Fern. Adiantum* is a large genus of ferns, several of whose species have been used in medicine, more especially the *A. capillus-veneris* L. of Europe and the *A. pedatum* L., growing throughout North America, except the far North and the Southwest, and abundant also in parts of Asia. The herb is the portion used. It has an aromatic-bitter taste, due to constituents which have not been studied. Its use is historical, it having been employed mainly in the treatment of catarrhal affections, especially of the respiratory tract. At the present time it is largely used in the manufacture of some patent medicines, but scarcely in any other way. HENRY H. RUSBY.

Fern, Male.—See *Aspidium.*

Fern, Sweet.—This name has been applied to a number of plants; to some true ferns, because of their fragrance; and to some flowering plants with leaves resembling those of ferns, especially to the *Comptonia peregrina* (L.) Coulter (fam. *Myricaceæ*), also called Fern-Bush, Fern-Gale, or Sweet Bush. It is exceedingly abundant in rocky meadows, especially amidst blueberry bushes, in northeastern North America. The leaves are peculiarly pinnatifid, with nearly semicircular segments alternating upon the two sides. They contain tannin, a small amount of an irritant glucoside, and a peculiar volatile oil, smelling like bay oil and somewhat like

cinnamon. This oil has a specific gravity of 0.926 and solidifies at a freezing temperature.

The leaves are useful as a mild astringent of delightful fragrance, and are at the same time markedly stimulant, owing to the oil. The bark also contains tannin and is used as an astringent. The dose of the leaves is gr. xv.–xxx. (1.0–2.0); of the bark, twice as much.

Myrrhis odorata Scop. (fam. *Umbelliferæ*) has also been called sweet fern. It is the sweet chervil of Europe and its root is used as a carminative.

HENRY H. RUSBY.

Ferns.—(Nat. ord. *Filicineæ* or *Filices.*) This immense and interesting class of exquisitely beautiful plants has, unfortunately, but limited practical applications outside of decorative art. A few species yield extractible amounts of starch, while the rhizomes or young shoots of others are cooked and eaten. Dye-stuffs are yielded by a number, while several contain cumarin. There are many species which, although used to a large extent, and with good results, as domestic remedies, are not known to professional medicine. The commonest property, perhaps, is that of being anthelmintic, and many species of many genera, especially of *Pteris*, *Dryopteris* (incorrectly called "Aspidium"), and *Polypodium*, are so used. Many of these are poisonous, resembling in this respect the male fern. Next in importance are the astringent properties, due to tannin-like constituents, for which a very great number are in native use. In one or two cases, like that of *cibotium*, the hemostatic effects are mechanical, after the fashion of lint. Many species are distinctly diuretic, and a few carminative, while a great number, like hart's-tongue or scolopendrium, are in use as pectorals. The gummy exudation from incisions in some of the South American tree ferns forms a most useful, permanent, and elastic protective covering to slight wounds.

HENRY H. RUSBY.

Ferrein, Antoine.—Born at Frespech, October 25, 1693. Uncertain at first what profession to embrace, he studied theology, law, and medicine, but finally chose the latter, the study of which he pursued with ardor at Montpellier, where he received his doctorate in 1728. Two professorial chairs at the university becoming vacant soon after, he entered the competition and was unanimously selected as the first of the three candidates. His rivals had more influence, however, and were appointed by the king. Ferrein was naturally incensed at this show of favoritism and left Montpellier in anger, going to Paris where he became very successful as a teacher of anatomy. He was sent to Italy as physician in chief of the military hospitals and on his return was commissioned by the government to investigate the sweating sickness then prevailing. In 1741 he was elected a member of the Académie des Sciences, and the following year was appointed to the chair of surgery at the Collège de France. In 1758 he was chosen professor of anatomy in succession to Winslow. He died of apoplexy, February 28, 1769.

Among the works published by Ferrein were the following: "Sur la structure de la foie et de ses vaissaux, 1733; "Observations sur de nouvelles artères et veines lymphatiques," 1741; "De la formation de la voix de l'homme," 1741; Sur le mouvement des deux machoires," 1744; "Sur l'inflammation des viscères du bas-ventre," 1766; "Sur le véritable sexe de ceux qu' on appelle hermaphrodites," 1767. In his work on the formation of the human voice he called attention to the fact that the larynx is a musical instrument, and described the vocal cords. Among the eponyms to which his name is attached are Ferrein's canal (rivus lacrimalis), Ferrein's cords (the true vocal cords), Ferrein's foramen hiatus canalis facialis, Ferrein's pyramid (the pars radiata of a cortical lobule of the kidney), and Ferrein's tubes (the convoluted tubules of the kidney).

T. L. S.

Ferris Hot Springs.—(Bozeman Hot Springs), Gallatin County, Montana.

POST-OFFICE.—Bozeman. Hotel.

ACCESS.—Ferris or Bozeman Hot Springs property is situated on the Gallatin Valley Electric Railway. The main line of the Northern Pacific Railway runs through Bozeman, eleven miles distant, reached by the Gallatin Valley Electric and the Chicago, Milwaukee, and Puget Sound Railways. The Gallatin Valley Electric Railway connects Bozeman and Salesville through the Bozeman Hot Springs tract. The Gallatin Valley branch of the Milwaukee road connects Bozeman Hot Springs with Three Forks and Butte on the main line of the Chicago, Milwaukee, and Puget Sound Railway.

These springs are located on the east bank of the West Gallatin River, seven miles by wagon road and eleven miles by rail, west of Bozeman. They were discovered about forty years ago. About twenty years ago Mr. Ferris bought the Springs and erected a handsome modern hotel, improved the natural charming surroundings, and placed the resort on a par with the most attractive in the West. Since then the property has again changed hands. The location of the hotel possesses unusual advantages. To the northeast and south a broad expanse of level country stretches out, dotted here and there with groves of cotton-wood and poplars, the intervening ground being occupied by fields of growing grain and verdant meadow lands. On the west the river sweeps along in magnificent curves, the line of tall trees conforming to the meanderings of the stream. Back of all, the grand old Rockies—snow-crowned, rock-ribbed, majestic—form an apparently unbroken guard to the enchanting scenes which lie in tranquil loveliness below. The location is 4,500 feet above the sea-level. Fish and game are found in great abundance and variety in the neighborhood. An analysis of the waters by Messrs. Riggs and Clark of the United States Geological Survey in 1885 resulted as follows:

Solids.	Grains to imp. gal.	Grams to liter.
Silica	5.782	0.0826
Sodium silicate	7.686	0.1098
Calcium carbonate	2.730	0.0390
Magnesium carbonate	0.252	0.0036
Sodium carbonate	5.250	0.0758
Potassium chloride	0.938	0.0134
Sodium chloride	4.949	0.0707
Sodium sulphate	13.818	0.1974
Loss	0.070	0.0010
Total	41.475	0.5933

The analysis shows sufficient sulphate of sodium to give the waters a laxative effect when taken in considerable quantities. They are recommended, both for internal use and for bathing, particularly in cases of gout, rheumatism, and diseases of the kidneys and liver. The cleansing properties of these waters is remarkable, no soap being necessary. On skin diseases their effect is pronounced, a short series of baths leaving the skin clear, white and smooth.

EMMA L. WALKER.

variable quantity of diffusible substances which might react to ninhydrin, it is necessary to obtain the specimen after the completion of digestion. It is best drawn directly from the vein into a sterile centrifuge tube. It is centrifuged after coagulation and the clear serum pipetted off into a clean sterile tube. The presence of hemolysis in any degree is said to render the serum unfit for use.

All glassware must be scrupulously clean and sterile. For the performance of the test 20 c.c. of sterile distilled water is placed in each of a sufficient number of small tubes or Erlenmeyer flasks and covered with a layer of toluol. The diffusion shells are washed in distilled water and boiled in water for one-half to one mintue. Five-tenths gram of the prepared albumin is placed in each shell, 1.5 c.c. of serum and a layer of toluol added. The top is carefully closed and the outside washed off with sterile distilled water. The shell is then placed in the tube in such a manner that the portion containing the serum is completely exposed to the water outside. All of the manipulations are to be carried out in such a manner that sterility is preserved. They are then incubated at 37° C. for sixteen hours. At the end of this time 10 c.c. of the dialysate is removed, free from toluol, and boiled for exactly one minute with 0.2 c.c. ninhydrin. The development of a violet color within thirty minutes indicates a positive reaction. There should be ample control of each test using normal and inactivated serum as well as the specimen being investigated. If possible a known positive control should also be employed.

In pregnancy the test has proven very reliable, at least as far as intrauterine pregnancy is concerned. It becomes positive during the second month and disappears within about one month after delivery. In other conditions the results reported thus far are not sufficient grounds on which one might form any conclusions. It has been reported as positive in the majority of carcinomata and in a large percentage of the cases of exophthalmic goiter. In cases of dementia præcox positive results have been obtained with tissue from the cerebral cortex and the ovaries and testicles. The absolute specificity of the reaction is stoutly asserted by some investigators and questioned by others who speak of "group reactions." The ultimate truth will probably be found to lie in some middle ground and the test itself will come to have marked value. RALPH G. STILLMAN.

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Fernel, Jean.—This most celebrated of the French physicians of the sixteenth century was born at Clermont in 1496. He was of a most studious disposition and eager for learning, and his native place not affording what he needed, he went early to Paris, where he gave himself up to a study of mathematics and philosophy. His health soon broke down under the strain and while he was recuperating in the country he became interested in medicine. On returning to Paris he took up this study, supporting himself by teaching philosophy. He began the practice of his profession in 1536. Fernel was a profound student and greatly preferred the science to the art of medicine, avoiding practice as far as he could. But in spite of himself he soon acquired such fame that Henri II wished to appoint him his own physician, but he resisted for a long time under one pretext and another. Finally, however, he was forced to yield and accompanied the

FIG. 2372.—Jean Fernel.

king to the siege of Calais, but soon after his return to Fontainebleau he fell ill from exposure during the inclement winter, and died April 26, 1558.

Among the many works, mathematical, philosophical, and medical, written by Fernel, we may mention the following: "Cosmotheoria," Paris, 1528, in which he suggested measuring one degree of the meridian of the earth, thus foreshadowing the foundation of the metric system of weights and measures; "De Abditis Rerum Causis," Paris, 1548; "Medicina," Paris, 1554, ten editions; "Therapeutices Universales" in seven volumes, Paris, 1554; "De Luis Venereæ Curatione," Antwerp; "Pathologia," Frankfort; "Emissi Sanguinis Observatio." T. L. S.

Fern, Maiden-Hair.—ADIANTUM. *Venus-Hair Fern. Adiantum* is a large genus of ferns, several of whose species have been used in medicine, more especially the *A. capillus-veneris* L. of Europe and the *A. pedatum* L., growing throughout North America, except the far North and the Southwest, and abundant also in parts of Asia. The herb is the portion used. It has an aromatic-bitter taste, due to constituents which have not been studied. Its use is historical, it having been employed mainly in the treatment of catarrhal affections, especially of the respiratory tract. At the present time it is largely used in the manufacture of some patent medicines, but scarcely in any other way. HENRY H. RUSBY.

Fern, Male.—See *Aspidium*.

Fern, Sweet.—This name has been applied to a number of plants; to some true ferns, because of their fragrance; and to some flowering plants with leaves resembling those of ferns, especially to the *Comptonia peregrina* (L.) Coulter (fam. *Myricaceæ*), also called Fern-Bush, Fern-Gale, or Sweet Bush. It is exceedingly abundant in rocky meadows, especially amidst blueberry bushes, in northeastern North America. The leaves are peculiarly pinnatifid, with nearly semicircular segments alternating upon the two sides. They contain tannin, a small amount of an irritant glucoside, and a peculiar volatile oil, smelling like bay oil and somewhat like

cinnamon. This oil has a specific gravity of 0.926 and solidifies at a freezing temperature.

The leaves are useful as a mild astringent of delightful fragrance, and are at the same time markedly stimulant, owing to the oil. The bark also contains tannin and is used as an astringent. The dose of the leaves is gr. xv.–xxx. (1.0–2.0); of the bark, twice as much.

Myrrhis odorata Scop. (fam. *Umbelliferæ*) has also been called sweet fern. It is the sweet chervil of Europe and its root is used as a carminative.

HENRY H. RUSBY.

Ferns.—(Nat. ord. *Filicineæ* or *Filices.*) This immense and interesting class of exquisitely beautiful plants has, unfortunately, but limited practical applications outside of decorative art. A few species yield extractible amounts of starch, while the rhizomes or young shoots of others are cooked and eaten. Dye-stuffs are yielded by a number, while several contain cumarin. There are many species which, although used to a large extent, and with good results, as domestic remedies, are not known to professional medicine. The commonest property, perhaps, is that of being anthelmintic, and many species of many genera, especially of *Pteris*, *Dryopteris* (incorrectly called "Aspidium"), and *Polypodium*, are so used. Many of these are poisonous, resembling in this respect the male fern. Next in importance are the astringent properties, due to tannin-like constituents, for which a very great number are in native use. In one or two cases, like that of *cibotium*, the hemostatic effects are mechanical, after the fashion of lint. Many species are distinctly diuretic, and a few carminative, while a great number, like hart's-tongue or scolopendrium, are in use as pectorals. The gummy exudation from incisions in some of the South American tree ferns forms a most useful, permanent, and elastic protective covering to slight wounds.

HENRY H. RUSBY.

Ferrein, Antoine.—Born at Frespech, October 25, 1693. Uncertain at first what profession to embrace, he studied theology, law, and medicine, but finally chose the latter, the study of which he pursued with ardor at Montpellier, where he received his doctorate in 1728. Two professorial chairs at the university becoming vacant soon after, he entered the competition and was unanimously selected as the first of the three candidates. His rivals had more influence, however, and were appointed by the king. Ferrein was naturally incensed at this show of favoritism and left Montpellier in anger, going to Paris where he became very successful as a teacher of anatomy. He was sent to Italy as physician in chief of the military hospitals and on his return was commissioned by the government to investigate the sweating sickness then prevailing. In 1741 he was elected a member of the Académie des Sciences, and the following year was appointed to the chair of surgery at the Collège de France. In 1758 he was chosen professor of anatomy in succession to Winslow. He died of apoplexy, February 28, 1769.

Among the works published by Ferrein were the following: "Sur la structure de la foie et de ses vaissaux, 1733; "Observations sur de nouvelles artères et veines lymphatiques," 1741; "De la formation de la voix de l'homme," 1741; Sur le mouvement des deux machoires," 1744; "Sur l'inflammation des viscères du bas-ventre," 1766; "Sur le véritable sexe de ceux qu' on appelle hermaphrodites," 1767. In his work on the formation of the human voice he called attention to the fact that the larynx is a musical instrument, and described the vocal cords. Among the eponyms to which his name is attached are Ferrein's canal (rivus lacrimalis), Ferrein's cords (the true vocal cords), Ferrein's foramen (hiatus canalis facialis), Ferrein's pyramid (the pars radiata of a cortical lobule of the kidney), and Ferrein's tubes (the convoluted tubules of the kidney).

T. L. S.

Ferris Hot Springs.—(Bozeman Hot Springs), Gallatin County, Montana.

POST-OFFICE.—Bozeman. Hotel.

ACCESS.—Ferris or Bozeman Hot Springs property is situated on the Gallatin Valley Electric Railway. The main line of the Northern Pacific Railway runs through Bozeman, eleven miles distant, reached by the Gallatin Valley Electric and the Chicago, Milwaukee, and Puget Sound Railways. The Gallatin Valley Electric Railway connects Bozeman and Salesville through the Bozeman Hot Springs tract. The Gallatin Valley branch of the Milwaukee road connects Bozeman Hot Springs with Three Forks and Butte on the main line of the Chicago, Milwaukee, and Puget Sound Railway.

These springs are located on the east bank of the West Gallatin River, seven miles by wagon road and eleven miles by rail, west of Bozeman. They were discovered about forty years ago. About twenty years ago Mr. Ferris bought the Springs and erected a handsome modern hotel, improved the natural charming surroundings, and placed the resort on a par with the most attractive in the West. Since then the property has again changed hands. The location of the hotel possesses unusual advantages. To the northeast and south a broad expanse of level country stretches out, dotted here and there with groves of cotton-wood and poplars, the intervening ground being occupied by fields of growing grain and verdant meadow lands. On the west the river sweeps along in magnificent curves, the line of tall trees conforming to the meanderings of the stream. Back of all, the grand old Rockies—snow-crowned, rock-ribbed, majestic—form an apparently unbroken guard to the enchanting scenes which lie in tranquil loveliness below. The location is 4,500 feet above the sea-level. Fish and game are found in great abundance and variety in the neighborhood. An analysis of the waters by Messrs. Riggs and Clark of the United States Geological Survey in 1885 resulted as follows:

Solids.	Grains to imp. gal.	Grams to liter.
Silica	5.782	0.0826
Sodium silicate	7.686	0.1098
Calcium carbonate	2.730	0.0390
Magnesium carbonate	0.252	0.0036
Sodium carbonate	5.250	0.0758
Potassium chloride	0.938	0.0134
Sodium chloride	4.949	0.0707
Sodium sulphate	13.818	0.1974
Loss	0.070	0.0010
Total	41.475	0.5933

The analysis shows sufficient sulphate of sodium to give the waters a laxative effect when taken in considerable quantities. They are recommended, both for internal use and for bathing, particularly in cases of gout, rheumatism, and diseases of the kidneys and liver. The cleansing properties of these waters is remarkable, no soap being necessary. On skin diseases their effect is pronounced, a short series of baths leaving the skin clear, white and smooth.

EMMA E. WALKER.

Ferrum.—Iron.—I. General Medicinal Properties of Compounds of Iron.—All iron preparations capable of absorption are qualified, in some degree, to exert a peculiar influence upon nutrition generally. Given to a person in health, the influence appears to be slight, since the clinical symptoms are insignificant. A rather hard and quickened pulse, a feeling of fulness and tension of the head, and dull pains and discomfort, generally, constitute about all the obvious derangement. When, however, the mineral is administered to a sufferer from anemia of the ordinary type, or from chlorosis, much more marked effects follow. The morbid conditions, in these diseases, that are the expression of deficient hemoglobin tend to subside with greater or less rapidity; the pale, waxy skin becomes rosy, the flabby tissues become firm, weight increases, appetite is gained, and in every way the invalid improves in health and strength. In pernicious anemia, however, iron is commonly without effect.

The clinical results thus seen to follow the medicinal giving of iron, both in health and disease, obviously suggest that the action of the drug is to determine an increase in the quantity of hemoglobin present in the circulation, either by enrichment in hemoglobin of the red blood corpuscles, or by a quickening in the rate of evolution of these bodies, or possibly by both means combined. Exact observations on the blood of anemics and chlorotics during a course of iron show that the medicine is indeed capable of producing both the effects described. With large doses, the tendency is first to increase the hemoglobin richness of the red corpuscles, and later the number of the globules; with small doses, to reverse this order of proceeding. Probably, in either case, the essential action of the iron is to determine hemoglobin enrichment, the effect on rate of corpuscular evolution being a secondary consequence. How iron accomplishes this feat is, as usual in the matter of the action of a medicine, entirely unknown. The original idea was the simple one that since in chlorosis there is a deficiency of hemoglobin, medicinal iron is absorbed and appropriated to make good the deficit, and that is the whole of the story. Later, however, it was observed that even when iron is given in quantities enormously in excess of physiological needs, the normal trace of iron occurring in the urine is not increased. Accordingly, it was argued that no excretion by the kidneys of adventitious iron must mean none to excrete, and therefore that medicinal iron is not absorbed. So came about theories of the action of iron in chlorosis based on the different chemical behavior of iron when in ordinary saline combination, on the one hand ("inorganic" iron, so called), and, on the other, in that peculiar combination in which the metal occurs as a constituent of the animal body, as in hemoglobin ("organic" iron). "Inorganic" iron is precipitated from solutions by alkaline sulphides, but "organic" iron resists such attack unless the sulphides are present in excess. According to the theory, therefore, ordinary medicinal iron, being, as it is, "inorganic" iron, is all precipitated by the sulphides of the alimentary canal, and consequently is not absorbed at all. "Inorganic" iron, then, can cure chlorosis indirectly only, by promoting in some way assimilation of the "organic" iron of the subject's dietary. And two such ways have been assumed: the one, by simple improvement of digestion generally, through local action of medicinal iron upon the intestine, and the other by vicarious sacrifice of the "inorganic" iron itself as follows: It is assumed (Bunge) that in chlorosis there is an excess of sulphides in the primæ viæ whereby even the "organic" iron of the foods is attacked and precipitated. By reason of such precipitation, then, the food iron is not absorbed in full, and the chlorotic condition results. But if now a chalybeate is taken, the sulphides seize upon such "inorganic" iron in preference to the "organic" food iron, and so the latter is saved for absorption.

But to this theory of the non-absorption of "inorganic" iron there are fatal objections. First, under the theory, anything else than iron equally effective either to improve digestion or to precipitate sulphides ought to be just as good as iron for curing chlorosis, whereas such is distinctly not the case. Secondly, iron should be inoperative if introduced in the form of sulphide into the intestine; but again the fact is the other way. Thirdly and conclusively, absorption of "inorganic" iron introduced into the alimentary canal has positively been demonstrated, and in different ways, by a number of experimenters upon animals.

The non-excretion by the kidneys of ingested iron is very simply explained by the fact that, as in the case of other heavy metals, iron is excreted mainly by the *intestines*. The history of iron in the animal system is undoubtedly this: It is absorbable from the intestines, whether originally presented as "inorganic" or "organic" iron; and, after absorption, so much as may be wanted for physiological needs is stored away, mainly in the liver and spleen, thence to be put forth, as may be required, in the form of "organic" iron. What is absorbed in excess of needs is excreted, but this excretion, as just said, is principally by the same avenue as that of entry into the system, namely, by the intestines.

It is unfortunate that the theory of non-absorption of "inorganic" iron should have gained such vogue as has been the case. For the result has been, on the one hand, undeservedly to discredit the ordinary chalybeates, and, on the other, to flood the market with new and expensive preparations purporting to offer iron in a condition especially fit for assimilation, when, as a matter of fact, the standard and cheap preparations of the Pharmacopœia are just as good.

Being itself a normal constitutent of the animal substance, iron is non-poisonous so far as constitutional effect is concerned in any ordinary dosage. Locally, however, there is the widest possible difference in the action of the different iron preparations, some being absolutely bland, while others are irritant or astringent and styptic.

The character of an iron compound, *in re* astringency or irritation, is determined in part by the solubility of the salt, and in part by the character of the salt's acid radical. For, of course, in the first place, all compounds insoluble, or but sparingly soluble, in fluids of aqueous basis are locally bland, so that metallic iron, ferrous carbonate, and ferric hydroxide and hypophosphite, are bland irrespective of the quality of their several acids. Of aqueously soluble compounds, those that are salts of the so-called organic acids—acetic, citric, and tartaric—and the mixed salts of the United States Pharmacopœia passing under the names of "phosphate" and "pyrophosphate," are comparatively bland—the citrates, tartrates, and phosphates being quite so, the acetate not so purely. The salts of the strong so-called mineral acids are in varying degree astringent, irritant, or both, as follows: Powerfully styptic, are *ferric chloride*, and the two grades of *ferric sulphate*, normal and basic ("tersulphate" and "subsulphate," respectively); powerfully astringent, but with proportionately less coagulating faculty, *ferrous sulphate* ("green vitriol," "sulphate of iron") and *ammonio-ferric sulphate* ("iron-alum"); decidedly irritant, but not distinctively astringent, *ferrous iodide*. True "organic" iron is always bland.

Clinically, the respective local effects of the two broad groups thus defined are as follows: The astringent or irritant compounds have a harsh, *puckery*, generally sour and disagreeably inky taste, and, upon frequent taking, tend to blacken and even to corrode the teeth. The blackening is removable by a toothbrush, but the corrosion is, of course, a serious matter,

and necessitates the clinical rule to order solutions of astringent chalybeates to be taken through a glass tube set far back over the tongue, and the mouth to be well rinsed after the swallowing. Upon the healthy stomach, small doses of the astringents, in common with most other not overnoxious irritants, tend to excite appetite and quicken digestion, but large doses to derange. Upon a stomach the seat of a decided catarrh—as is unfortunately often the case in the very circumstance of anemia calling for chalybeate medication—even comparatively small doses act so unkindly that the astringents have to be set aside and a bland chalybeate substituted. Upon the bowels there is a strong tendency to constipate—so strong that in a considerable course of medication with an astringent iron salt the condition of the bowels must carefully be watched and regulated. In overdose the astringents are irritant poisons—fatal, it may be, in sufficient volume and concentration of solution.

Of these various effects there is seen but a shadow, or not even that, among the bland preparations. Some of the soluble ones may taste a little inky and blacken the teeth, but they do not corrode. Some tendency to constipation may be noted, but far less in degree than with the astringent compounds; while severe irritation of the stomach, poisoning, and local stypticity are entirely wanting. Chalybeates of the bland group that are insoluble of course have practically no taste and absolutely no astringency, and do not blacken the teeth. After being swallowed such preparations are attacked by the free acid of the gastric juice, and being changed thereby to soluble form, are capable of absorption, and thus of full chalybeate constitutional power.

All chalybeates, finally, bland and astringent, blacken the stools by their presence therein in the condition of tannate or sulphide. These derived salts thus discharged in the *dejecta* may, in part, represent a certain portion of the iron dose that has entered the blood, and, after a due career in the circulation, has been excreted by the bowels, and in part they may be and undoubtedly are, the simple excess of dose that, unabsorbed, has been passed along the alimentary canal to the rectum. Of course, the blackening of the stools is of no consequence; the only point is that the patient should be forewarned of the circumstance, lest the unusual color of the feces excite alarm.

Therapeutically, the two main applications of iron compounds are their internal administration for the cure of *anemia*—in which case the medicine is referred to as a *chalybeate*—and the local use of the ferric styptics for the control of hemorrhage. There are, however, certain special applications of certain compounds which will be detailed in due place.

II. Medicinal Preparations of Iron.—The preparations of iron official in the United States Pharmacopœia are derived from the following chemical conditions of the metal: 1. The metal uncombined, in state of powder. 2. The metal in ferrous combination, as, severally, *carbonate, sulphate,* and *iodide.* 3. The metal in ferric combination, as, severally, *hydroxide acetate, citrate, ammoniocitrate, potassiotartrate, ammoniotartrate, sodiophosphate* ("phosphate"), *sodiopyrophosphate* ("pyrophosphate"), *hypophosphite, chloride, basic sulphate* ("subsulphate"), *normal sulphate* ("tersulphate"), and *ammoniosulphate.* These several compounds will be discussed seriatim, together with the preparations of the United State Pharmacopœia derived from each.

Iron uncombined, metallic iron, in the condition of fine powder, is a valuable chalybeate of the bland variety, characterized by richness, tastelessness, and perfect blandness, combined with promptness and efficiency. Because of these qualities, metallic iron is especially serviceable in the case of children or of subjects of any age with sensitive stomachs or squeamish palates. Iron in powder is easily obtainable by reducing ferric oxide, heated in a reduction tube, by a stream of hydrogen gas. The product is official in the United States Pharmacopœia under the title *Ferrum Reductum,* Reduced Iron, also known as *Quevenne's iron,* and *iron by hydrogen.* Reduced iron, pulverulent at the forming, is subjected to further fine pulverization, and then appears as a soft, smooth, heavy powder of a lusterless, blackish-gray hue. It is, of course, insoluble in neutral fluids, such as water, alcohol, or glycerin, but it dissolves, with effervescence of hydrogen, in dilute acids, by entering into saline combination therewith. Its medicinal activity is determined by this reaction, the acids of the gastric juice acting as solvents. Reduced iron should be kept, well dried, in a tightly stoppered bottle, in order to prevent oxidation, a reaction to which the preparation is very prone. Purity is important, since impure specimens give rise to eructations of disagreeable gas after taking. A good sample is a gray-black, and not deep black, and on treatment with dilute sulphuric acid, warmed, dissolves wholly, and the hydrogen gas evolved is nearly without odor. Black specimens, effervescing but slightly with dilute acids, are spurious.

The dose of reduced iron ranges from gr. iij. to vi. (0.2–0.4), given three times a day. Being tasteless, the preparation may be given, even to children, in powder, or it may be ordered in pill, or, convenient for children, in chocolate lozenge. The administration should be at or about meal-times, so as to secure the prerequisite of presence of acid gastric juice; and if digestion be sluggish, it is well even to add an acid, for which purpose the innocent acid of lemonade is perfectly efficient.

Ferrous Carbonate ($FeCO_3$), also insoluble, closely resembles reduced iron in combining perfect blandness with efficiency. But since the salt undergoes rapid spontaneous decomposition, it is available for prescribing only in certain pharmaceutical preparations wherein decomposition is prevented by the presence of sugar. These preparations, in the United States Pharmacopœia, are as follows:

Ferri Carbonas Saccharatus, Saccharated Ferrous Carbonate. A solution of ferrous sulphate is added to one of sodium bicarbonate; ferrous carbonate forms as a pale, bluish-white precipitate, which is collected, washed, drained, and, while still moist, mixed with sugar. Then the mixture is dried over a water-bath, and the product is pulverized. Such powder is to be kept in small bulk, in tightly stoppered bottles. Saccharated carbonate of iron thus made is a dull, greenish-brown powder of a saccharine and faintly ferruginous taste. It is neutral in reaction; in water only the sugar of its composition dissolves, but in dilute acids the entire powder disappears by chemical conversion of the iron salt, the reaction attended by copious evolution of carbon dioxide. The dose is from gr. v. to xv. (0.3–1.0), three times a day, given in a powder or pill. But if the pill form be desired, the following official preparations are better:

Massa Ferri Carbonatis, Mass of Ferrous Carbonate, known also as *Vallet's mass,* or *Vallet's ferruginous pills.* Ferrous carbonate is precipitated as in making the foregoing preparation, but now from a syrupy instead of from a simple aqueous solution of ferrous sulphate, and syrup instead of plain water is used for the washings. The protective influence of sugar is thus utilized from the start, with the result of securing a quite perfect preservation of the ferrous salt. After collection, the precipitate of the carbonate is incorporated with honey and sugar, and the mixture evaporated to a certain weight. A greenish-black, soft, pilular mass results. The mass contains about half its weight of the iron salt, and may be given in doses, thrice daily, of from gr. iij. to v. (0.2–0.3), of course in pill.

Pilulæ Ferri Carbonatis, Pills of Ferrous Carbonate, "Ferruginous Pills," "Chalybeate Pills," "Blaud's Pills." These pills are an imitation of the famous

French "*Fraud's ferruginous pills,*" and are compounded of ferrous sulphate, potassium carbonate, sugar, tragacanth, and althæa, made into pilular consistence with a few drops of glycerin and water. The usual double decomposition occurs between the ferrous sulphate and the alkaline carbonate, with the production of ferrous carbonate. The pills should be made freshly when wanted, and two or three may be given at a dose.

Ferrous carbonate is the salt of iron present in the following preparation of the United States Pharmacopœia, designed to afford the association of iron with myrrh for prescription to women, when anemia is complicated with menstrual debility or an hysterical tendency:

Mistura Ferri Composita, Compound Iron Mixture, "Griffith's Mixture." In this mixture, rose-water, flavored with spirit of lavender, and charged with the necessary sugar, holds in suspension myrrh and ferrous carbonate, the latter precipitated by mixture of ferrous sulphate and potassium carbonate. The mixture, despite the sugar present, does not keep well, and should be made fresh on prescription. From one-half to an ounce may be given three times a day.

Lastly, ferrous carbonate is the condition in which iron exists ordinarily in chalybeate waters, the salt being held in solution by the excess of carbonic acid with which the waters are charged. The rust-colored deposit which these waters yield is due to the ferric hydroxide resulting from the usual spontaneous decomposition of the carbonate.

Ferrous Sulphate ($FeSO_4.+7H_2O$) is the salt so well known as *green vitriol*, and also in the impure state as *copperas*. Medicinally, it is of triple interest, being efficient as a chalybeate, an astringent, and a disinfectant. The salt can be obtained in the condition of large crystals, crystalline grains, and in the powder that results from depriving the crystals, by efflorescence and heat, of the greater part (six molecules) of their water of crystallization. All three conditions are official in the United States Pharmacopœia, the crystalline being entitled *Ferri Sulphas*, Ferrous Sulphate; the granular, *Ferri Sulphas Granulatus*, Granulated Ferrous Sulphate; and the powder of efflorescence *Ferri Sulphas Exsiccatus*, Exsiccated Ferrous Sulphate. The official crystals represent a pure form of the article, such as alone should be used if intended for internal administration. The crystals are large monoclinic prisms of a pale bluish-green color, and effloresce slowly on exposure. The crystalline grains—the "granulated sulphate" of the United States Pharmacopœia—result from pouring a solution of ferrous sulphate slowly, with constant stirring, into alcohol. The salt then, being insoluble in alcohol, separates in a crystalline powder, which powder is of the same tint as the ordinary crystals, and also effloresces in dry air. The third, the "exsiccated" form, is obtained by heating the previously effloresced salt so long as it yields water of crystallization, and then pulverizing. It is a fine, grayish-white powder, of which a little over three parts are the equivalent in chalybeate value of five of the crystals.

Ferrous sulphate in all its forms dissolves in water, the two varieties of crystals fully and freely, the effloresced powder more slowly and with a small residue. In alcohol it is insoluble. The salt, although not truly styptic, is strongly astringent and is capable, in overdose, of producing irritant poisoning. Medicinally it can be used as a chalybeate, and is important in being the only decidedly astringent chalybeate that can conveniently be given in pill form. When prescribed internally, therefore, it is commonly in such form, and for this the exsiccated sulphate should invariably be selected, since the crystals, by efflorescence, would tend to disintegrate a pill mass. The dose is from gr. i. to ij. (0.06–0.12), three times a day. If ordered in solution (in which condition, however, ferrous sulphate presents no particular reason for selection), one of the crystalline forms should be prescribed, and care should be taken to avoid in the solution any of the many chemical incompatibles of the salt. These are catalogued as the alkalies and their carbonates, soaps, lime water, calcic and basic chlorides, sodium borate and phosphate, silver nitrate, and lead acetate and subacetate.

If, furthermore, the iron sulphate contain any of the hydroxide, as it is very apt to do, anything charged with tannic or gallic acid, as are many vegetable infusions, will make ink on admixture. This reaction, however, can be prevented by the addition of a small quantity of any of the pharmacopœial dilute mineral acids—an addition rarely objectionable under the circumstances in which the chalybeate is likely to be prescribed. Ten drops of diluted sulphuric acid to about four fluidounces of a half-per-cent. solution of ferrous sulphate and tannic acid has been found competent to prevent the usual precipitation.

Ferrous sulphate can be used locally for the usual purposes of the mineral astringents, but is rarely so employed, since it presents no advantage over the time-honored salts of silver, copper, zinc, etc. If used, it is to be applied in solution, whereof the strength will range from one-fifth per cent. to about two per cent., according to the sensitiveness of the part; or it may be made into ointment of from one per cent. to three per cent. in strength.

Thirdly, ferrous sulphate has an old-time reputation as a so-called "disinfectant." Recent exact experiments have shown that the salt may fail utterly as a germicide, although capable, in 0.5 per cent. solution, to inhibit temporarily the vital activity of certain microorganisms. Limitations in the employment are that the salt, not being volatile, is useless for aerial disinfection, and that, because of its staining, it must not be employed to treat textile fabrics, floors, or walls. But for bed-pans, close stools, sinks, drains, cesspools, privies, etc., ferrous sulphate is unobjectionable, and has the positive advantages of being cheap and odorless. For application, the very cheap commercial copperas answers just as well as the pure pharmacopœial salt. A handful of the crystals may be put into a bed-pan or close stool that is to receive offensive or contagious discharges, or, where a solution is more convenient, this may be made of about fifteen per cent. strength, and should be used liberally. When large quantities are wanted, a convenient plan is to suspend a basket holding about sixty pounds of copperas in a barrel of water, from which barrel the solution is dipped out as wanted.

Lastly, concerning ferrous sulphate, it is the iron salt present in the official preparation of the United States Pharmacopœia entitled *Pilulæ Aloës et Ferri*, Pills of Aloes and Iron. (This preparation, being rather one of aloes than of iron, has been mentioned under *Aloes*, which see.)

Ferrous Iodide: FeI_2. In the medicinal virtues of ferrous iodide, the iodine, because of its small actual quantity in allowable doses of the compound, plays a very subordinate part. The salt salt is therefore essentially a chalybeate, with but a dash, so to speak, of iodine virtues. Ferrous iodide is irritant, without being astringent, and is somewhat remarkable for a tendency to relax rather than to constipate the bowels. It is sometimes also diuretic. As a chalybeate it is efficient, and is most commonly selected in cases in which the action of iodine is desired along with that of iron—this rather on theoretical grounds. It has been used in cases of tuberculous adenitis, rickets, and arthritis. Chemically, ferrous iodide, like the carbonate, is hopelessly unstable, so that the prescriber is again restricted to special pharmaceutical forms for the administration. These in the United States Pharmacopœia are as follows:

Syrupus Ferri Iodidi, Syrup of Ferrous Iodide. Fer-

rous iodide is formed in solution by bringing together iron wire and iodine in the presence of water, and the solution, with proper manipulations of heating and filtering, is mixed with syrup, of the proper quantity to make the product contain five per cent. of ferrous iodide. When freshly made this syrup is of a clear, pale-green color, is odorless, and of a combined sweet and harshly ferruginous taste. Despite the sugar in its composition, it is very prone to change, in which case the color passes from green to yellow, or even brown. This change occurs mainly through exposure to the oxygen of the atmosphere, the iodide being in part decomposed, the iron suffering oxidation, and the iodine being set free. To prevent change the syrup should be kept in small vials, well stoppered, fully filled, and exposed to diffused daylight. Syrup of ferrous iodide is a very frequently used and thoroughly efficient chalybeate. It is given in doses, thrice daily, of from ♏ viii. to xxx. (0.5–2.0), and should always be given well diluted with water, and without being mixed with any other drug. The medicine, furthermore, being very liable to attack the teeth, should be taken through a glass tube and the mouth well rinsed after each dose.

Pilulæ Ferri Iodidi, Pills of Ferrous Iodide. Iodine and reduced iron are made to react in presence of water, until all the iodine is converted into iodide. Then certain proportions of licorice, sugar, extract of licorice, and gum arabic are added, and the mixture is evaporated to pilular consistence. The mass is then cut up into pills, and the individual pills are coated with balsam of Tolu dissolved in a little ether, to protect them from the action of the atmosphere. These pills are in imitation of the so-called *Blancard's pills*, and are an efficient representative of the virtues of ferrous iodide. Each pill contains one grain of ferrous iodide, and one-fifth grain of reduced iron, and from one to two pills constitute a dose.

Ferric Hydroxide, is peculiar among the medicinal ferric compounds in being insoluble in water. Furthermore, it seems to resist obstinately the solvent powers of the alimentary juices, for when taken internally, even in quite large quantities, in anemia, it produces very little effect. Locally, as might be inferred, it is absolutely bland. Because of its feebleness, the hydroxide is practically useless as a chalybeate, and its medicinal value is solely because of a peculiar chemical reaction it affords with arsenical compounds, whereby it becomes a chemical antidote in poisoning by arsenic. The reaction is that ferric hydroxide, when freshly made and still moist, attacks arsenical compounds in solution, and forms out of them a ferrous arsenate which is insoluble, and therefore inert. So long as the arsenical is in solid condition there is no reaction, but as fast as solution takes place the hydroxide, if upon the ground, attacks the dissolved compound, as described. For the reaction in full, the estimate is that twelve parts of antidote are needed for each part of poison; but since the hydroxide is harmless, the practice is to give it freely and frequently so long as the symptoms of poisoning persist.

Ferric hydroxide is easily obtainable by treating with an alkali a solution of a ferric salt. The salt is decomposed, its acid radical going over to the alkali, and its basic precipitating as ferric hydroxide. The precipitate thus occurring is brick-red, pulpy, tasteless, and perfectly bland. Washed and mixed with the proper amount of water, it forms a magma, in which condition it is given in teaspoonful doses every five minutes, in application as antidote to arsenic. Two formulæ for procuring the hydroxide are authorized by the United States Pharmacopœia, and since the physician may need himself to prepare the antidote, the formulæ are here reproduced in full:

Ferri Hydroxidum, Ferric Hydroxide. "Solution of ferric sulphate, 100 c.c.; ammonia water, 138 c.c.; water, a sufficient quantity. To the ammonia water, previously diluted with 500 c.c. of cold water, add, with constant stirring, the solution of ferric sulphate, previously diluted with 1,000 c.c. of cold water. As soon as the precipitate has subsided, draw off the clear liquid by means of a siphon, then mix the precipitate intimately with about 1,000 c.c. of cold water, again draw off the clear liquid after subsidence of the precipitate, and repeat this operation until a portion of the decanted liquid gives not more than a slight cloudiness with barium chloride test solution. Finally, transfer the precipitate to a wet muslin strainer, and, after it has drained, mix it with sufficient cold water to make the mixture weigh 300 gm." (U. S. P.).

The objection to this process is the time consumed in the washing and straining, and, accordingly, the following preparation is offered, in which the hydroxide is precipitated by magnesia instead of ammonia, and the excess of magnesia and the magnesium sulphate resulting from the reaction with the iron sulphate are permitted to remain, since they are harmless. Accordingly the preparation is ready for use at once:

Ferri Hydroxidum cum Magnesii Oxido, Ferric Hydroxide with Magnesium Oxide. "Solution of ferric sulphate, 40 c.c.; magnesium oxide, 10 grams; water, a sufficient quantity. Mix the solution of ferric sulphate with 125 c.c. of water, and keep the liquid in a large, well-stoppered bottle. Rub the magnesium oxide with cold water to a smooth and thin mixture, transfer this to a bottle capable of holding about 1,000 c.c., and fill it with water to about about three-fourths of its capacity. When the preparation is wanted for use, shake the magnesium oxide mixture to a homogeneous thin magma, add it gradually to the diluted solution of ferric sulphate, and shake them together until a uniform, smooth mixture results. Note.—For the rapid preparation of this antidote to arsenical poisoning the diluted solution of ferric sulphate and the mixture of magnesium oxide with water, should always be kept on hand in separate bottles, ready for immediate use" (U. S. P.).

Of the next following salts of iron, the acetate and the various citrates, tartrates, and phosphates have so many features in common as to constitute a distinct subclass. These salts are all soluble in water, bland in action, and of little taste; they decompose spontaneously in aqueous solution, and, obtained in solid form by evaporation of such solution, present the appearance of thin, shining scales, looking like broken bits of thin, colored gelatin. They are valuable, medicinally, as affording bland chalybeates whose solubility and freedom from taste enable them to be given without objection in fluid form. They are common as the iron basis of many fancy fluid pharmaceutical preparations. They should be kept in well-stoppered bottles, protected from light.

Ferric Acetate: $Fe_2(C_2H_3O_2)_6$. Since acetic acid is a pretty sharp acid, ferric acetate has a sharp quality, and, accordingly, is not so purely bland as are the citrates and tartrates. It is an excellent chalybeate of its type, and is official in the United States Pharmacopœia, not in solid form, but only in the following pharmaceutical preparation:

Liquor Ferri et Ammonii Acetatis, Solution of Iron and Ammonium Acetate, Basham's Mixture. This solution is an elegant elixir, containing a weak charge of iron in condition of acetate. It is compounded of tincture of chloride of iron (four per cent.), diluted acetic acid, solution of ammonium acetate, aromatic elixir, glycerin, and water. By reaction the iron becomes the acetate, and part of the ammonium acetate becomes ammonium chloride, but the greater part of the ammonium salt remains unchanged. The preparation is a beautifully clear, reddish solution of agreeable elixir taste, with scarcely a trace of ferrugin-

ous flavor. For its strength it is efficient, and may be given in doses of a tablespoonful three or four times a day. It decomposes spontaneously on keeping for any length of time, and accordingly should be freshly made, when wanted. The pharmacopœial dose is four drams (16 c.c.).

Ferric Citrate: $Fe_2(C_6H_5O_7)_2+6H_2O$. Normal ferric citrate is peculiar, among the group under consideration, in that it dissolves quite slowly, although fully, in cold water, and when once insolution is comparatively stable. Because of slow solubility it is peculiarly fitted for prescription in pill. The salt is official as follows:

Ferri Citras, Ferric Citrate. "It should contain not less than sixteen per cent. of metallic iron and should be kept in well-stoppered bottles, protected from light. Thin, transparent, garnet-red scales, without odor, and having a slightly ferruginous taste. Slowly but completely soluble in water at 77° F., (25° C.) and readily soluble in hot water, but diminishing in solubility with age; insoluble in alcohol. Average dose four grains (0.250 gm.)" (U. S. P.).

Ferri et Quininæ Citras, Iron and Quinine Citrate. The above scaled preparation and quinine in the proportion of eighty-five of the former to twelve of the latter, are dissolved together in water, with the addition of a little free citric acid, and the solution is then evaporated for the yielding of scales. The product is in transparent, reddish or yellowish-brown scales, bitter and mildly ferruginous in taste, and dissolving, as does the simple citrate, completely but slowly in cold water. The scales should be kept in the dark, in well-stoppered bottles. They represent the ingredients probably in simple mixture only. The preparation affords a means of giving a chalybeate in conjunction with quinine; convenient where the indication fits the one proportion between the constituents which these scales provide, but otherwise not. The dose averages about gr. v., (0.30) representing rather less than gr. i. (0.06) of quinine, given, by natural selection, in pill.

Ammonio-ferric Citrate.—If the official solution of citrate of iron be charged with one-fourth of its weight of water of ammonia, and the mixture then evaporated in the usual manner, scales will be obtained identical in characteristics with the scales of the citrate already described, except that they dissolve rapidly instead of slowly in cold water. Such scales are regarded as representing a double citrate of the two bases, but the exact chemical constitution, as is the case with all the composite scale preparations, is difficult to determine. The preparation is official as *Ferri et Ammonii Citras*, Iron and Ammonium Citrate, and is medicinally convenient as a substitute for the simple citrate when the chalybeate is desired in solution. Pharmaceutically, it is the basis of the following:

Vinum Ferri, Wine of Iron. Four per cent. of the ammonio-citrate scales is dissolved in a mixture of tincture of sweet orange-peel, syrup, and white wine. This wine makes a weak chalybeate elixir, to be given in doses of a teaspoonful, representing about gr. iij. (0.2) of the iron compound.

Ferri et Strychninæ Citras, Iron and Strychnine Citrate. Scales of the ammonio-citrate are dissolved in water, and the solution is mixed with a solution of strychnine citrate, made by adding strychnine and citric acid together to water. From the mixed solution scales are obtained in the usual way. The composite scales thus derived are indistinguishable in appearance and solubility from those of the plain ammonio-citrate, but declare themselves by their bitter taste. They contain two per cent. of the citrate of strychnine, equivalent to a little less than one per cent. of the alkaloid itself. The average dose is about gr. ij. (0.125).

The ammonio-citrate also occurs in the following preparations:

Ferri et Quininæ Citras Solubilis, Soluble Iron and Quinine Citrate. This preparation is made of the same ingredients and in the same way as the simple iron and quinine citrate, but, by the addition of ammonia water to the solution before evaporation, the ammonio-citrate forms, and the resulting scales are rapidly and completely soluble in cold water. This preparation, accordingly, is to be selected when the double citrate is wanted in solution instead of in pill. The scales are of a greenish-yellow color.

Vinum Ferri Amarum, Bitter Wine of Iron. This wine is compounded of five per cent. of the foregoing soluble iron and quinine citrate, made into an elixir with tincture of sweet orange-peel, syrup, and white wine. It is given in teaspoonful doses.

Potassio-ferric Tartrate.—Although not selected for the making of fancy preparations, the potassiotartrate of iron is a valuable chalybeate, being of little taste, perfectly bland, and, perhaps because of the potassium tartrate of its composition, less disposed to constipate than the average of iron salts. The salt is official under the title of *Ferri et Potassii Tartras*, Iron and Potassium Tartrate, as a scale preparation, gotten in the usual way, from a solution resulting from admixture, in water, of fresh ferric hydroxide and acid potassium tartrate ("bitartrate"). The scales are garnet-red, similar in appearance to the scales of the citrate, and probably represent a double tartrate of the contained bases. The preparation is so bland that it may be given in comparatively large doses, ranging from gr. x. to xxx. (0.65–2), most naturally in solution.

Ammonio-ferric tartrate.—Is substantially a duplicate of the potassio-tartrate just described. It occurs in scales, derived from a solution wherein the salt is made by a process analogous to the foregoing. The preparation is official as *Ferri et Ammonii Tartras*, Iron and Ammonium Tartrate, and in appearance, solubility, and dose conforms to the example of the potassio-tartrate.

(*Sodio-*) *Ferric Phosphate.*—Under the title *Ferri Phosphas Solubilis*, Soluble Ferric Phosphate, the United States Pharmacopœia makes official a scale preparation containing sodio-ferric phosphate and obtained out of a solution in which ferric citrate has been decomposed by the addition of uneffloresced sodium phosphate. The preparation must not be confounded with a formerly official "phosphate," which consisted of the slate-colored, insoluble ferroso-ferric phosphate that precipitates from reaction of ferrous sulphate and sodium phosphate in solution. The scales of the present preparation differ from those of the citrates and tartrates in being of a bright-green color instead of garnet-red. They are bland, of little taste, and make an excellent chalybeate of their kind. Dose, from about gr. v. to x. (0.3–0.65), in pill or solution.

Compounded from these scales and from quinine, strychnine, and phosphoric acid is an official syrup entitled *Syrupus Ferri, Quininæ, et Strychninæ Phosphatum*, Syrup of the Phosphates of Iron, Quinine, and Strychnine. The dose is limited, by the presence of strychnine, to a teaspoonful, which quantity contains about gr. i. of the iron compound, gr. $1\frac{3}{4}$ of the quinine, and gr. $\frac{1}{60}$ of strychnine. This syrup does not keep well, and is at best an unnecessary preparation.

(*Sodio-*) *Ferric Pyrophosphate.*—Under the title of *Ferri Pyrophosphas Solubilis*, Soluble Ferric Pyrophosphate, a scale preparation is official in the United States Pharmacopœia, which is a twin brother of the "phosphate" described above, the mode of preparation being identical, except that sodium pyrophosphate is substituted for the ordinary orthophosphate. The present scales are apple-green in color, freely soluble, of little taste, and perfectly bland. They constitute, therefore, a favorite form for giving iron. Chemically, here, as also with the other "phosphate," the exact relation between the two acid and basic radicals represented in the two

salts conjoined in the preparation is not known. Dose, from gr. ij. to v. (0.12–0.3) three times a day, in pill or solution.

Passing from the scale preparations, other ferric compounds are as follows:

Ferric Hypophosphite ($Fe H_2PO_2)_3$.—The salt is official as *Ferri Hypophosphis*, Ferric Hypophosphite. It is a grayish-white powder, of little taste, permanent in air, only sparingly soluble in water, and insoluble in alcohol. It was introduced into medicine as a means of combining the virtues of a hypophosphite, as such, with those of iron. From the point of view of its qualities as a chalybeate, it is mild in operation, but feeble in effect. Dose, from gr. v. to x. (0.3–0.65) three times a day, in powder or pill.

The remainder of the iron salts, again, form a natural group. They are all ferric salts of the stronger so-called mineral acids, and are characterized by free solubility in water, and the possession of intensely strong astringent, or even, most of them, styptic, qualities. Their taste is harsh and puckery, with a combined, strong, inky, and acidulous flavor —on the whole, very decidedly disagreeable. With the exception of the ammonio-sulphate, they yield solutions of a color ranging from a golden-yellow to a deep orange or reddish-brown. They comprise the most powerful representatives, both of the chalybeate and hemostatic virtues of iron, and in overdose are capable of producing irritant poisoning.

Ferric Chloride ($FeCl_3+12H_2O$) commonly (formerly called also *sesquichloride* and *perchloride*), is the most powerful known combined chalybeate and styptic, and has the qualities mentioned above developed to the highest degree. It is official as follows:

Ferri Chloridum, Ferric Chloride. Iron wire is treated with dilute hydrochloric acid, whereby ferrous chloride forms, with effervescence of hydrogen. The solution of the ferrous salt is then treated with additional hydrochloric acid, followed by nitric acid, by which means the ferrous is converted into the ferric chloride. The resulting solution, which under the details of the process is hot and concentrated, becomes a crystalline mass on cooling. Ferric chloride, thus derived, is in lumps of crystalline texture, orange-yellow in color, without smell, but of a harsh, chalybeate, and sour taste. It deliquesces with great readiness, dissolves freely in water, and is also soluble in alcohol and ether. The salt is convenient for ordering in solution for styptic purposes; it is a powerful but harsh hemostatic. Applied to a bleeding part it forms, with the coagulable elements of the part, a reddish, slimy, pultaceous slough—an operation entailing a good deal of irritation. Because of such irritation, the sulphate of iron, which irritates much less, while it is hardly inferior in styptic power, is commonly preferred. If the chloride is used, and the bleeding area is small, as in the case of hemorrhage from a tooth socket, a concentrated application may be made by taking a drop or two of a deliquesced sample, or by mixing a small fragment of the solid stuff into a paste with a very little water. For more extended applications, solutions may be ordered of strengths ranging from five to twenty per cent. or so. Strong solutions, even so strong as fifty per cent., have been used to inject varicose aneurysms, but in some instances with fatal consequences.

Liquor Ferri Chloridi, Solution of Ferric Chloride. This is an original solution wherein ferric chloride is formed exactly as described above. It contains twenty-nine per cent. of anhydrous salt, with some free hydrochloric acid, and is a dark-reddish fluid. It may be used as a strong solution for styptic purposes, or in doses of a few drops, very largely diluted, as a chalybeate medicine, but its essential purpose is to afford the preparation next to be described.

Tinctura Ferri Chloridi, Tincture of Ferric Chloride. The above solution of the chloride is diluted with three times its own volume of alcohol, and the mixture is ordered to be kept before dispensing for at least three months. The object of the latter requirement is to afford time for a slow reaction that takes place between the free hydrochloric acid derived from the original iron solution and the alcohol, whereby an ethereal body is formed, which imparts the peculiar flavor to the tincture, and is commonly accredited—perhaps justly—with having something to do with the somewhat peculiar effects of this preparation. Tincture of ferric chloride is a clear, yellowish-brown fluid, of a rough, astringent, acid, and ferruginous taste. It is decomposed by alkalies, alkaline earths and their carbonates, astringent vegetable infusions, and mucilage of acacia. In its effects it is strong enough in ferric chloride to be locally styptic, and, if swallowed in considerable quantity, to set up irritant poisoning. Its almost sole application is as a chalybeate medicine, in which rôle it is unsurpassed. Besides being of avail in anemia and chlorosis, it often shows marked power in the individual diseases —acute tonsillitis, diphtheria, scarlet fever, and erysipelas—if given boldly in full doses. Moderate doses, furthermore, will often seem to oppose, so far as medicines can, the progress of kidney degeneration. In prescribing this tincture it must be borne in mind that it is a powerful medicine; that even in moderate doses it tends to blacken, if not to injure, the teeth, to irritate the stomach, and constipate the bowels, while in large doses it may cause, in addition, headache and irritation of the genitourinary tract. Yet in the acute diseases mentioned above, in which large doses are so commonly prescribed, the medicine is remarkably well borne. The dose of the tincture ranges from ♏ ij. to x. or so, three times a day, in anemia, to a teaspoonful, or more even, every hour or two, in the grave diseases requiring full dosage. The medicine must be well diluted, at least fourfold, with water, and the addition of some glycerin—about twenty-five per cent. of the potion as swallowed—remarkably disguises the harsh, unpleasant taste of the draught without affecting its efficiency. The dose should be sucked through a glass tube and the mouth well rinsed after the swallowing, and the administration should be preferably a while after meals rather than before. In anemia good results often follow the giving of small and copiously diluted doses of the tincture—two drops diffused through a tumblerful of water. And thus administered, the medicine is practically freed from the objectionable taste and irritant action on the stomach which often preclude its use in larger dosage.

Basic Ferric Sulphate, $Fe_2(SO_4)_3+4Fe_2O_3$.—This salt closely resembles the chloride in intense styptic quality, yet differs from the same in the advantageous way of being decidedly less irritant. It is official in the United States Pharmacopœia only in an original solution, as follows:

Liquor Ferri Subsulphatis, Solution of Ferric Subsulphate, "Monsel's Solution." Ferrous sulphate in a fixed proportion is added to a mixture in fixed proportion of sulphuric and nitric acids, at the boiling temperature. Conversion of the ferrous to the ferric sulphate results, but, by virtue of the proportion of sulphuric acid taken, it is the basic salt that forms. After the reaction is complete the solution is brought, by the addition of distilled water, to the standard strength—a strength corresponding to about 13.6 per cent. of metallic iron (U. S. P.). This solution is a deep ruby-red fluid, analogous in all general characteristics to the solution of the chloride. It is especialy intended and used as a styptic, in which capacity it is pre-eminent.

Solution of the subsulphate may be applied clear to parts within reach; may be swallowed in ten-drop doses, well diluted, in hematemesis, and inhaled in atomized spray, in a two percent. aqueous dilution,

in hemoptysis. The solution is also, of course, a possible chalybeate medicine, but, having no especial advantage over the tincture of the chloride, is rarely used for its medical virtues. The dose would be ten drops or so, largely diluted. This solution is the one formerly known as "solution of persulphate of iron"; and is dispensed whenever such solution is prescribed.

Normal Ferric Sulphate, $Fe_2(SO_4)_3$.—The normal sulphate differs, medicinally, from the basic only in being more irritant in its local effects. It is official in the United States Pharmacopœia for pharmaceutical purposes only, and in the following original solution:

Liquor Ferri Tersulphatis, Solution of Ferric Sulphate. This solution is made in precisely the same manner as the foregoing, only with such proportion of the ingredients as to yield the normal instead of the basic sulphate. It is of a strength corresponding to about ten per cent. of metallic iron. It is important as being the preparation out of which ferric hydroxide is made, both when this compound is called for as an antidote to arsenic, and also when it is required for the making of the scale preparations of iron, as already seen. This solution is efficient as a chalybeate and as a hemostatic, but, having no advantages for such application, is rarely so used.

Ammonio-ferric Sulphate, $FeNH_4(SO_4)_2+12H_2O$.—The salt is official under the title *Ferri et Ammonii Sulphas*, Ferric Ammonium Sulphate, "Iron Alum." It has the chemical structure and, physiologically, the peculiar strong astringency, without excessive irritation, of the true alums. It occurs in octahedral crystals of a delicate lilac or violet color, which dissolve freely in water, but are insoluble in alcohol. It is used in strong solution, as a styptic, or internally, as a combined astringent and chalybeate, in cases of anemia. Dose, from gr. v. to x. (0.3–0.65) three times a day.

Besides the foregoing official preparations there are numerous others, not official either because now dismissed from the Pharmacopœia as obsolete, or because not deemed worthy of recognition, or because newly proposed.

Dialyzed iron at one time had considerable vogue in medicine, although never recognized by the United States Pharmacopœia. As a chalybeate it is bland, but feeble, and as an antidote to arsenic—its other possible application—it is considered inferior to the "ferric hydroxide with magnesium oxide," on the score that the insoluble compound that it forms with the arsenical is less stable in the presence of acids.

Genuine dialyzed iron is a clear, reddish-brown solution, odorless, practically tasteless, and perfectly bland and innocent. Any decidedly ferruginous or styptic taste probably means a sham specimen. The true article mixes in all proportions with distilled water, alcohol, glycerin, and simple syrup; but upon admixture with alkalies, many salts—notably sodium chloride—and most organic matters, it suddenly transforms itself into a soft gelatinous mass, in color and consistence much resembling clotted blood. Such reaction must inevitably ensue on swallowing, and in the colloidal state resulting the iron is incapable of absorption. What of dialyzed iron ever gets access to the blood must, therefore, be through some chemical attack upon it by the alimentary juices, with the development of new and soluble iron compounds. The dose of dialyzed iron must be large if any effect at all is to be expected—at least a teaspoonful of the usual ten-per-cent. solution three times a day. As an antidote to arsenic, teaspoonful doses should be given every five minutes; and since now gelatinizing is of advantage, some common salt should follow each dose.

Organic Compounds of Iron.—A distinct class of preparations is afforded by certain compounds of iron with *protein* substances, designed to furnish iron in a condition allied to the "organic" iron of hemoglobin, and this because of the notion that ordinary iron preparations are not capable of assimilation (see *ante*). Of these preparations the most important are those containing iron as an *albuminate* or a *peptonate*.

By reaction of solution of ferric chloride upon albumin *ferric albuminate* forms, which precipitates from the solution by addition of a solution of common salt. The precipitate, washed and dried, appears as a brown powder, soluble in water. Dose, gr. xx.–xxx. (1.3–2.0). In this preparation the iron is not in the condition of "organic" iron, for a solution of the albuminate precipitates with alkaline sulphides the same as does a solution of an ordinary salt of iron.

Ferric Peptonate.—A solution of freshly peptonized albumin is treated with dialyzed iron, and from the solution of ferric peptonate finally obtained scales are prepared in the usual way. These scales are brown in color, contain about one-quarter of their weight of iron, and dissolve slowly in cold water. They make a bland chalybeate, in which, however, as in the case of ferric albuminate, the iron is in "inorganic" and not "organic" condition.

In addition to the preparations mentioned above, the following are also used in place of the inorganic salts.

Arsenoferratose is a proprietary article containing arsenic, albumin, and iron.

Arsentriferrol is a solution of triferrin and arsenogen which latter contains arsenic, phosphorus, nitrogen, and iron.

Bivo is a beef and iron wine. Dose one teaspoonful.

Carniferrin is a compound of iron with phosphocarnic acid. It is in the form of powder, tasteless and bland; is soluble in alkaline fluids, and may be given as a chalybeate in doses of a few grains. It contains about thirty per cent. of iron.

Carniferrol is a liquid preparation of iron and meat peptone.

Ferralbumose is another preparation in form of powder, obtained by precipitating with a solution of ferric chloride a solution of albumose derived from meat by treatment with artificial gastric juice.

Ferrarin is a solution of iron arsenate, and has been used hypodermatically in some cases of anemia secondary to phthisis.

Ferratin is a preparation made to imitate the normal ferratin discovered by Schmiedeburg in the liver of the hog. It is made by reaction of albumin with a double tartrate of iron and one of the alkali metals. The preparation is in the form of a brownish powder, almost insoluble in water but soluble in alkaline liquids. It contains from six to eight per cent. of iron. It is claimed that in ferratin the condition of the iron is certainly very near to that of natural "organic" iron, but yet the preparation reacts with the hematoxylon test, which true "organic" iron does not do.

Ferratogen is an insoluble yellowish powder made as follows: yeast is grown on a medium containing iron; the nuclein thus formed being isolated and digested with gastric juice, then washed with alcohol containing hydrochloric acid. It represents one per cent. of iron and is said not to be affected by the gastric juice, and to be well absorbed in the intestine.

Ferratose is a sweetened solution of ferratin.

Ferrinol is an iron nucleid containing about six per cent. of iron.

Ferroplasma is derived from *Rumex*, and contains iron in organic combination.

Ferropyrine is an orange-colored powder made by acting on antipyrine with ferric chloride. It contains sixty-four per cent. of antipyrine and twelve per cent. of iron is soluble in water and alcohol, and is said to have remarkable styptic properties without caustic effects. It is used in twenty per cent. to full strength as a styptic in uterine and other hemor-

rhages, in one to two per cent. solution as an astringent in gonorrhea, and in dose of gr. v. to xv. (0.3–1.0) internally for anemia and chlorosis.

Ferrosol is a saccharated ferrous oxide with sodium chloride.

Ferrostyptin is probably a combination of iron and urotropin; it is used locally, as a styptic, in a twenty per cent. solution.

Fersan is an acid albumin obtained from erythrocytes, and is a ferruginous nutritive containing a high percentage of phosphorus. It is said to rank high as a hematinic and as an albuminoid food. Dose gr. xv. to xxx. (1.0–2.0) three times a day.

Hemaboloids is a proprietary article said to contain a vegetable iron with peptone, bone-marrow, and nuclein.

Hemalbumin contains hematin, hemoglobulin, paraglobulin, serum albumin, and the inorganic constituents of blood.

Hematicum is a red-brown, clear hydroalcoholic liquid containing indifferent compounds of iron.

Hematogen is a preparation, said to contain eighty parts of hemoglobin and twenty parts of glycerin.

Hematol is a sterilized hemoglobin containing glycerin and brandy.

Hemogallol is an indifferent preparation of iron obtained by the reducing action of pyrogallol on the hemoglobin of ox-blood. It is a red-brown powder the iron of which is not changed to chloride by the gastric juice. Dose gr. v. to xv. (0.3–1.0).

Hemol, a congener of hemogallol, is obtained by the reduction of hemoglobin with zinc dust. This substance has been combined with various metals forming:

Arsenohemol containing one per cent. of arsenous acid.

Bromohemol containing 2.7 per cent. of bromine.

Copper-hemol containing two per cent. of copper.

Hydrargyro-iodo-hemol containing 12.35 per cent. of mercury and twenty-eight per cent. of iodine.

Iodohemol containing 16.6 per cent. of iodine.

Zinc-hemol containing one per cent. of zinc.

Ovoferrin has nothing to do with yolk of egg. It is a protein-iron compound derived from blood serum and solution of ferric hydroxide.

Triferrin also called *ferrinol* contains phosphorus and a nuclein in addition to the iron. Dose about five grains three times a day.

Triferrol is the fluid equivalent of triferrin.

Other organic iron preparations are the ammonium arsenocitrate, caseinate (nucleo-albuminate), dextrinate, glycerophosphate, inulate, malate, and vitellinate (iron and egg yolk) of iron, iron and sodium albuminate and citroalbuminate, hematinalbumin, hemochromogen, hemoferrum, hemoglobin, methemoglobin, pepto-ferromangan, and ferrosomatose (two per cent. iron).

The various protein preparations of iron have the certain merit that they do not upset the stomach and that they are readily absorbed. They are, however, comparatively expensive, and it is not demonstrated that they cure chlorosis any more effectively than well-selected preparations from among the pharmacopœial list.

III. General Therapeutics of Iron Compounds.—Excepting certain special applications of individual compounds, the therapeutics of iron comprises the internal use for the cure of anemic conditions, and the local employment for astringent or styptic purpose. Concerning the two applications, the following practical points are to be made:

Anemia.—(1) Except in pernicious anemia, iron proves so serviceable that, given an anemic state, the medicine is commonly held to be indicated, unless there be either fever or a tendency to active hemorrhage—conditions apt to be aggravated by iron. (2) In the matter of choice of preparations, in general, the astringent chalybeates are more powerful than the bland, but yet it will be wiser to try the latter kind first if either the stomach be over-irritable, the bowels strongly prone to constipation, the teeth fragile, or the patient of careless habits; or if, as with children, the disagreeable taste of the astringent preparations be particularly obnoxious. On the other hand, the astringent chalybeates are especially advantageous when the appetite is poor and yet the stomach is not unduly sensitive, or when there is general laxity of tissue, or a tendency to passive fluxes or hemorrhages. (3) In particular, concerning the preparations, if an astringent be wanted, the tincture of the chloride answers every purpose as a fluid form, and the dried sulphate (ferrous) as one for giving in solid form in pill. If a bland compound be required, there may be prescribed, in powder, reduced iron and the saccharated carbonate; in pill, reduced iron, pills of the carbonate, "Blaud's pills," and the citrate; and in solution, the potassio-tartrate or the pyrophosphate, with the others of the scaled preparations as substitutes. For the rest, the various compound salts and the fancy pharmaceutical preparations are often convenient, but are never indispensable. (4) The frequency of dosage is most conveniently fixed at three times a day, and the doses, as already given, are intended for such frequency. But in exceptional uses of iron, as of the tincture of the chloride in diphtheria, the frequency will be far different—according to the severity of the case, even to hourly administration, day and night. (5) The timing of the doses is best arranged to be at meal-hours, the administration to be rather after than before eating. This certainly with the astringent chalybeates, but with the very bland the rule need not be enforced.

To Arrest Hemorrhage.—(1) In general, it must be remembered that arterial hemorrhage belongs by right to the domain of surgery, and that medicinal hemostatics are only proper when the vessel is either too small for mechanical measures or is inaccessible. This rule needs especial observance in connection with the iron styptics, for if they fail to stop the bleeding the surgical search for the bleeding point, through the indiscriminately slough-obscured tissue resulting from the styptic application, is made exasperatingly difficult. Furthermore, this same slough caused by the styptic seriously interferes with speedy healing of the wound. (2) Of the styptic preparations the official solution of the subsulphate is generally the best, because the least irritant; but if extreme power be required, and the area to be subjected to the application is small, a drop or two of the deliquesced chloride may be allowed.

The individualized applications of iron compounds are of the hydroxide, as an antidote to arsenic; of ferrous sulphate, as a disinfectant; of the tincture of the chloride as a medicine of peculiar virtues; of the solution of ferric sulphate for purposes of pharmacy, and of the ammonio-sulphate as a pure astringent.

Edward Curtis.
R. J. E. Scott.

Fetus, Development of the.—Our knowledge of the development of the fetus was in an exceedingly fragmentary condition until Wilhelm His, the distinguished German anatomist, published about twenty-five years ago his noteworthy "Anatomie menschlicher Embryonen." This was one of the first and is to-day one of the most important works on human embryology. A multitude of articles and monographs have appeared since then in foreign and American scientific journals, as well as several comprehensive manuals and text-books. Among the latter the reader is referred for fuller accounts to such works as Keibel and Mall, "Manual of Human Embryology," 1910; Kollmann, "Handatlas des Entwicklungsgeschichte des Menschen," 1907; Keibel und Elze, "Normentafel

z. Entwicklungs-geschichte des Menschen," 1908; Broman "Normale und Abnorme Entwicklung des Menschen," 1911. The great difficulty in obtaining embryos of the first two months of pregnancy renders progress comparatively slow. The main sources of such material are from postmortem examinations, operations, and abortions; so the human embryologits is thus dependent upon the courtesy of physicians and surgeons for his material.

Age.—In regard to the ages of embryos of the first two weeks much uncertainty exists. Length is not entirely reliable, owing to distortions and variability in size. In attempting to determine age from the last day of the last menstrual period as the date of conception, there is often the difficulty of inexact history. The following table indicates in a fairly accurate way the length and ages of embryos:

Age.	Length.	Age.	Length.
Two weeks.....	2 mm.	Three months.....	50 mm.
Three weeks.....	5 mm.	Four months.....	100 mm.
Four weeks.....	8 mm.	Five months.....	200 mm.
Five weeks.....	11-12 mm.	Six months.....	300 mm.
Six weeks.....	16 mm.	Seven months.....	370 mm.
Seven weeks.....	20 mm.	Eight months.....	425 mm.
Eight weeks.....	25 mm.	Nine months.....	500 mm.

According to Mall their ages in days corresponds to the formula $\sqrt{100}\times$ (length in millimeters) for all embryos from 1 to 100 millimeters long. Multiply the length of the embryo from vertex to the breech in millimeters by one hundred, and extract the square root, and the result will be its age in days. In embryos from 100 to 220 millimeters long from vertex to breech their length in millimeters equals their age in days. Fig. 2373 indicates the relative sizes during the first eight weeks.

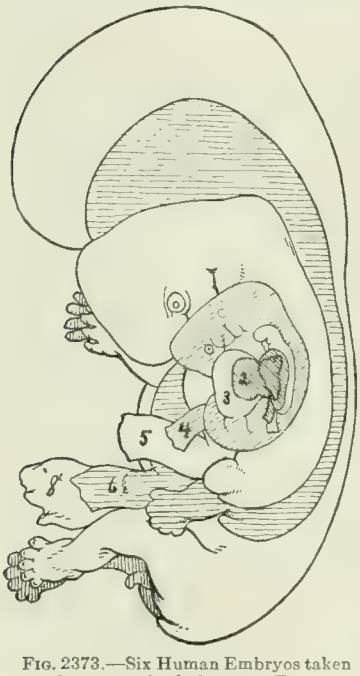


Fig. 2373.—Six Human Embryos taken from His' Standard Chart. Enlarged three times. The figures in the cut indicate the ages of the embryo in weeks. 2 is His' embryo S R.; 3, embryo Lr.; 4, embryo A.; 5, embryo C″; 6½, embryo XCI.; 8, embryo Wt. (After Mall.)

There are but few good collections of embryos in the world; the one at Baltimore is the most important.

In development it is convenient to distinguish the three stages suggested by His. The stage of the ovum embraces the first two weeks; the embryonal stage from the third to the fifth week, during which time the characteristic embryonal features and the principal organs are established; lastly the fetal stage, during which time the embryonal features change to those of the fetus and full-term child.

The Ovum Stage.—There are no observations on normal ova of the first nine or ten days. It is evident from the material of the latter part of the stage of the ovum that there is an early and precocious development of the chorion and villi.

The youngest known normal ovum was described by Peters in 1899. It is ten to eleven days old and consists of a vesicle $3\times1.5\times1.5$ millimeters in size. A section through the entire ovum is seen in Fig. 2374. The vesicle is formed by the chorionic membrane, consisting of an outer layer of epithelial cells covered by numerous villi which are in contact with the uterine wall of the mother, and an inner layer of mesenchyme. Attached to this inner layer at one side is the small embryo, but 0.19 millimeters in length. It is apparently simple in structure, consisting of an epithelial plate facing the small amniotic cavity lined by flat epithelial cells, which are continuous with the epithelial cells of the plate. On the other side of the plate is a layer of mesenchyme, and projecting from this is the yolk sac lined by entodermal cells. The epithelial plate of the embryo, as well as the epithelium of the amnion, was probably at an earlier stage continuous with the epithelium of the chorion and the embryo, subsequently cut off after its sinking down or projecting into the vesicular cavity. One stage of such a process has been found in the monkey by Selenka. The projecting embryo is surrounded by mesenchyme continuous with that lining the chorion, as well as with that between the yolk sac and epithelial plate.

Already, then, in the youngest known ovum the so-called three primary germ layers are present. From these at a later period various structures arise. From the epithelial layer develop the epidermis of the skin and its appendages, such as hairs, nails, sweat glands, etc., the central nervous system, and portions of the eye and ear, mouth and nose. From the middle or mesenchymal layer develop the skeletal, muscular, circulatory, and urogenital systems; and lastly from the inner or entodermal layer, which is here represented by the lining of the yolk sac, develop the alimentary tract (pharynx, esophagus, stomach, and intestines), the trachea and lungs, liver and pancreas, and bladder.

The next important human ovum was described by Spee in 1896. It measures 7×5.5 millimeters and the embryo within is 0.37 millimeters in length. Its age is about eleven days. The chorion is covered with villi and lined with mesenchyme (see Fig. 2375). The embryo is attached at one side by a broad pedicle, the so-called belly stalk. The amniotic sac is small and is continuous with the epithelial plate of the embryo, as in the preceding ovum. The primitive streak is represented in this embryo by a slight groove along the center of the epithelial plate. Mesenchyme separates the epithelial plate from the large yolk sac, and a small diverticulum of the sac projects into the mesenchymal pedicle, constituting the first trace of the allantois. We thus see that the embryo in this ovum, although about twice as long as the Peters embryo, shows very little advance in structural differentiation. Both are in the primitive streak stage.

Spee also described an ovum $10\times8.5\times6.5$ millimeters containing an embryo 1.54 millimeters in length and about eleven and one-half days old. The chorion is covered by large branching villi, lined by mesenchyme, and attached at one side by a short pedicle is the embryo (see Fig. 2376). The primitive streak still persists, and near its anterior end the neurenteric canal has formed, thus connecting the amniotic cavity with the yolk sac. All traces of it are soon lost. More anteriorly still are traces of two longitudinal ridges, short distances on either side of the median line. These are the so-called medullary folds and are the first traces of a differentiation for the central nervous system. The allantois as in the preceding embryo projects from the yolk sac into the pedicle or belly stalk.

Between this stage and the next one we shall consider, the embryonic plate changes from a flat discoidal structure to a somewhat cylindrical body by a bending ventrally of its lateral edges, to which the amnion is attached, thus gradually constricting the

broad attachment of the yolk sac. At the same time the head and tail ends begin to project more and more, and the yolk sac is thus also constricted in an anterior posterior direction. Connecting pockets of the yolk sac remain at both the head and tail ends of the embryo to form the beginnings of the digestive tract. During this time the medullary folds have lengthened and grown toward each other, so as to meet in the mid-dorsal line, thereby enclosing a central canal, the beginning of the central canal of the spinal cord and the ventricles of the brain. In the next oldest ovum we are to consider, which was described by Eternod, there was an embryo 2.11 millimeters in length. The medullary folds have not only met, but are fused for a considerable portion of their length to form the neural tube (see Fig. 2377). The head of the embryo now projects some distance beyond the constricted yolk sac, and on the ventral side of this head fold is a slight invagination of the ectoderm for the mouth. Between the mouth invagination and the attachment of the yolk sac the heart is in the process of development from two lateral tubes, which soon fuse together to form the simple tubular heart. The blood-vessels which have developed in the extra embryonic area and those that have developed in the body of the embryo have now become connected with the heart, and at its head end arises the ventral aorta dividing immediately into three pairs of branchial arches, which pass around the primitive foregut to unite beneath the medullary plate into the dorsal aorta. From the dorsal aorta are given off the omphalo-mesenteric and the umbilical arteries. The first veins to develop are those which accompany the first formed arteries, namely, the omphalo-mesenterics, connected with the yolk sac, and the umbilicals, connected with the allantois. Soon after these are formed the veins within the body of the embryo develop, the first ones being the anterior cardinals, or internal jugulars and the inferior cardinals, the latter draining the blood from the caudal portion of the body. An anterior and a posterior cardinal of each side unite to form the ductus Cuvieri. The two ducts, one on either side, pass transversely toward the median line and open into the sides of the sinus venosus. The omphalo-mesenteric veins coming from the yolk sac and the umbilicals from the allantois join the sinus venosus at a slightly earlier date than do the Cuvierian ducts. At a later stage we shall see how this primitive arrangement is modified to form the adult condition. The yolk sac in this embryo is somewhat constricted along its attachment, leaving pockets of entoderm connected with it that lie in the head and tail ends of the embryo. They form the primitive foregut and hindgut. At either side of the neural tube the mesenchyme has become differentiated into eight primitive segments or myotomes, from which later much of the muscular system becomes differentiated.

Fig. 2374.—Peters' Early Ovum. (Enlarged about thirty-five diameters.) *U.E.*, Uterine epithelium; *Bl.L.*, lakes of blood; *Caps.*, decidua reflexa; *G.P.*, "Gewebspfropf"; *Dr.*, [illegible]; *U.Z.*, decidua vera; *Tr.*, trophoblasts; *C.*, capillaries; *K.A.*, beginning embryo; *Bl.G.*, large blood-vessels; *a–b*, point of entrance of ovum.

A slightly older embryo, of about the same length, described by Mall, consists of an ovum measuring 18×8×8 millimeters, and containing an embryo 2.1 millimeters in length. The age is about two weeks (see Fig. 2378).

Many important changes have taken place. The embryo is connected to the chorion by a thinner stalk of mesenchyme containing the blood-bessels that carry on the circulation between the embryo and chorion, the latter being in close contact with the uterine wall, and thus affording opportunity for nourishment and oxygen to pass from the mother through the thin walls of the villi, to supply the rapidly growing embryo with the essentials for growth and life. The embryo itself has greatly increased in length, and is curved into a

semicircular form. The medullary plate is converted into a tube and the groove into its canal. At the anterior end of this tube are enlargements marking the beginnings of the brain. The remainder of the tube forms the spinal cord. The yolk sac, which is covered by blood-vessels that communicate with those of the

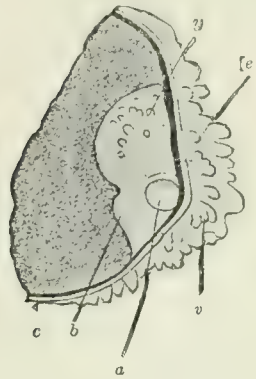


Fig. 2375.—Ovum Measuring 6×4.5 mm. (Enlarged about 10 diameters.) The left half of the chorion has been removed to show the embryo. *a*, Amniotic cavity; *b*, belly stalk; *c*, chorion; *e*, embryonic disc; *v*, chorionic villus; *y*, yolk-sac. (von Spee.)

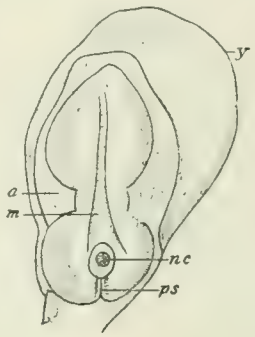


Fig. 2376.—Embryo 1.54 mm. in Length, from the Dorsal Surface. (Enlarged about 20 diameters.) *a*, Amnion; *m*, medullary groove; *nc*, neurenteric canal; *ps*, primitive streak; *y*, yolk sac. (von Spee.)

embryo, is more constricted and the fore- and hindguts are longer than in the preceding stage. From the foregut arises the pharynx with two gill pockets and a thyroid pocket. The neurenteric canal connects the hindgut with the central canal of the central nervous system. So while from the yolk sac are differentiating the two ends of the alimentary tract, the main portion is still embodied in the large sac. Near the origin of the foregut is a slight projection of the yolk sac for the beginning of the liver. In the anterior wall of the yolk sac, posteriorly to the mouth and beneath the pharynx, is the tubular heart. There are now fourteen pairs of mesenchymal segments or myotomes—three in the head, eight in the neck, and three in the thoracic region. The amnion at this period forms a small sac about the dorsal surface of the embryo.

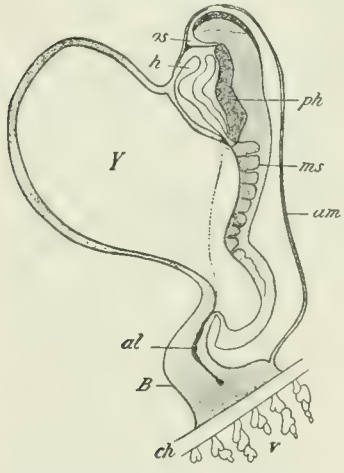


Fig. 2377.—Reconstruction of Embryo 2.11 mm. Long. (Enlarged about 25 diameters.) *al*, Allantois; *am*, amnion; *B*, belly stalk; *ch*, chorion; *h*, heart; *ms*, mesodermic somite; *os*, oral fossa; *ph*, pharynx; *v*, chorionic villi; *Y*, yolk-sac. (After Eternod.)

In an embryo described by Kollmann (Fig. 2379), and measuring 2.5 millimeters in length, the edges of the medullary folds have come in contact throughout their entire length except for a short distance anteriorly, and thirteen pairs of mesodermic somites or myotomes are visible. The constriction of the yolk sac is even more pronounced than in the preceding embryo, and the hind end of body has become defined, the belly stalk no longer seeming to be a posterior continuation of the body, but arises from the ventral surface. The oral fossa is more marked.

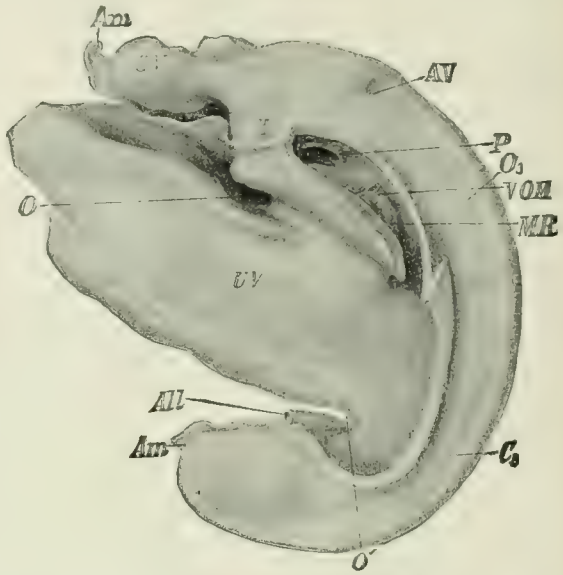


Fig. 2378.—Profile Reconstruction of the Embryo, 2.1 mm. Long. No. XII. × 35 times. *Am*, Amnion; *OV*, optic vesicle; *AV*, auditory vesicle; *UV*, umbilical vesicle; *H*, heart, *VOM*, omphalo-mesenteric vein; *MR*, septumt ransversum; *O*3, third occipital myotome; *C*8, eighth cervical myotome. (After Mall.)

The general shape of this embryo is quite different from that of the preceding one, the embryo being nearly straight; and it has probably been distorted, as has also the His embryo (Fig. 2380), as the normal curve of the medullary tube at this period is probably somewhat semicircular, as seen in Fig. 2378. This so-called dorsal flexure, which is often pictured in text books as a normal condtiion at this stage. I have been able to produce in pig embryos of a corresponding stage by rough handling while removing them from the uterus. Others from the same uterus, which were more carefully handled, do not show such a dorsal flexure, and we naturally conclude that similar treatment has produced a similar effect in the human embryo.

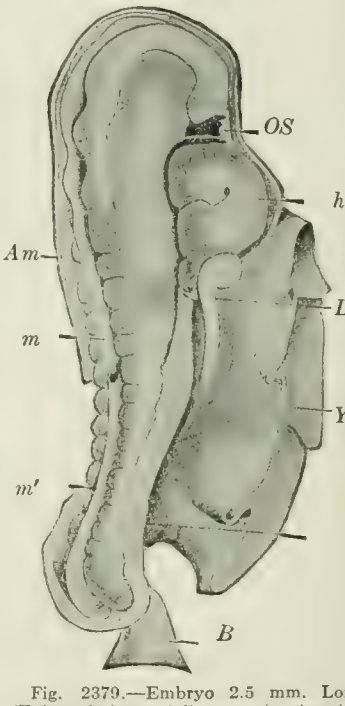


Fig. 2379.—Embryo 2.5 mm. Long. (Enlarged about 33 diameters.) *Am*, Amnion; *B*, belly stalk; *h*, heart; *m*, closed and *m'*, still open portions of the medullary groove; *Om*, omphalomesenteric vein; *OS*, oral fossa; *Y*, yolk sac. (Kollmann.)

The His embryo Lg, 2.15 millimeters long, contained in an ovum 15×12.5 millimeter, is the next important

one to consider. Its age is about fourteen days. (Fig. 2380). The forebrain has a marked ventral bend. Between the forebrain and the heart is now a well-marked invagination of the skin to form the mouth cavity. It is not as yet connected with the pharynx. Projecting from the forebrain are the optic vesicles, and farther back are invaginations of the ectoderm for the internal ear. Two gill clefts and

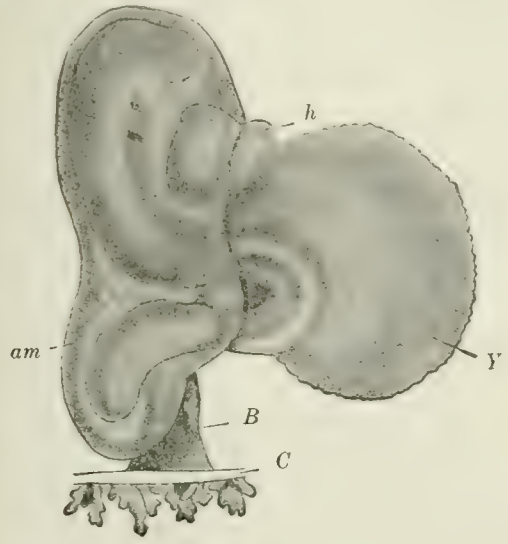


Fig. 2380.—Embryo Lg., 2.15 mm. Long. (Enlarged about 30 diameters.) *am*, Amnion; *B*, belly stalk; *C*, chorion; *h*, heart; *Y*, yolk sac. (His.)

three branchial arches are present, and branches of the aorta pass through the latter. The heart consists of a much bent tube.

The branchial arches and clefts are of great morphological importance, since they determine to a large extent the arrangement of the various organs of the head region. In the human embryo four clefts and five branchial arches appear on each side. The last arch is very indistinct.

We thus see that during the first two weeks, which constitute the ovum stage, there has developed from the simple one-celled ovum or egg an embryo with its membranes, the amnion and chorion, the latter having over its entire surface numerous long branching villi, and in the embryo are already present the beginnings of the central nervous system, the alimentary tract, the circulatory system, the muscular and skeletal systems, the latter being represented by the chorda dorsalis, which has differentiated from the dorsal wall of the entodermal sac and canal. The primitive urogenital system has also begun to appear. The yolk sac remains throughout this stage the dominant feature of the embryo.

The Embryonal Stage.—During the third week the embryo grows rapidly in size and attains a length of about four millimeters. The brain increases in size and shows the three primary divisions. The optic and otic vesicles become more prominent. Two more gill clefts and three more gill arches appear caudal to the ones already formed. The attached area of the yolk sac has diminished. The mouth cavity communicates with the pharynx. By the twenty-first day the limb buds appear (see Fig. 2381). Internally the heart is enlarged and takes the form of an S-shaped tube. From the aorta now arise five pairs of arteries which pass through the five pairs of gill arches, joining on the dorsal side of the pharynx into the common dorsal aorta.

By the narrowing of the attachment of the yolk sac more of the primitive gut has been folded off, so that now the foregut, midgut, and hindgut, are to be distinguished. In the foregut can already be made out the pharynx with its diverticula, the esophagus, and the stomach. Of the pharyngeal diverticula there are four pairs of gill pockets corresponding to the gill clefts on the external surface and separated from the gill clefts by a thin membrane. The diverticulum for the respiratory tract has begun to bud from the esophagus. The first indication of the lungs and trachea is found in embryos of about 3.2 millimeters in length in the form of a groove, the pulmonary groove, along most of the ventral surface of the esophagus. During the embryonal stage this groove deepens especially toward the stomach, where it ends in a rounded projection, which lengthens and gives off branches. These, by repeated branching, give rise to the various-sized bronchi and the epithelial portion of the lungs. The pulmonary groove gradually becomes constricted off from the esophagus to form the trachea. At the upper end, however, it remains open into the pharynx, in the region of the fourth branchial diverticulum, to form the glottis. The midgut gives rise to the small intestine and to a portion of the large intestine. From it have arisen diverticula which give rise to the liver and pancreas. The hindgut gives rise to the rest of the large intestine and to the rectum.

The primitive urogenital system has appeared as two longitudinal ridges projecting into the celom along its dorsal wall, one at either side of the median line in the posterior half of the embryo. This ridge contains the

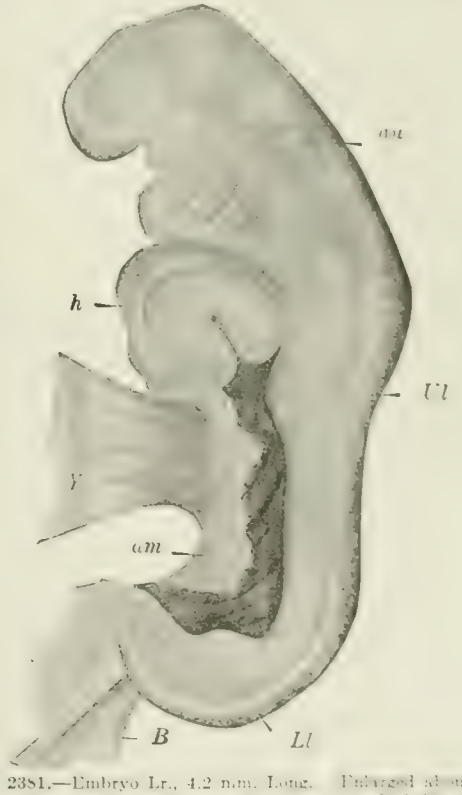


Fig. 2381.—Embryo Lr., 4.2 mm. Long. Enlarged about 28 diameters.) *am*, Amnion; *au*, auditory capsule; *B*, body stalk; *h*, heart; *Ll*, lower and *Ul*, upper limb; *Y*, yolk-sac. (His.)

Wolffian duct, the pronephros with its two tubules and rudimentary glomeruli. The Wolffian duct, which is the first to appear, develops from the mesenchyme, and extends from the heart region to the cloaca. Soon after the non-functional pronephros is formed, the mesonephros begins to develop and its tubules join the Wolffian duct. The mesonephros is a much more

important structure than the pronephros, and we shall consider it again later. The beginning of the Müllerian duct is also present at this stage.

During the fourth week growth is relatively more active than at any other time, except during the very early stages of the first week or ten days. The embryo about doubles in length, and attains a length by the end of this week of about six or seven millimeters.

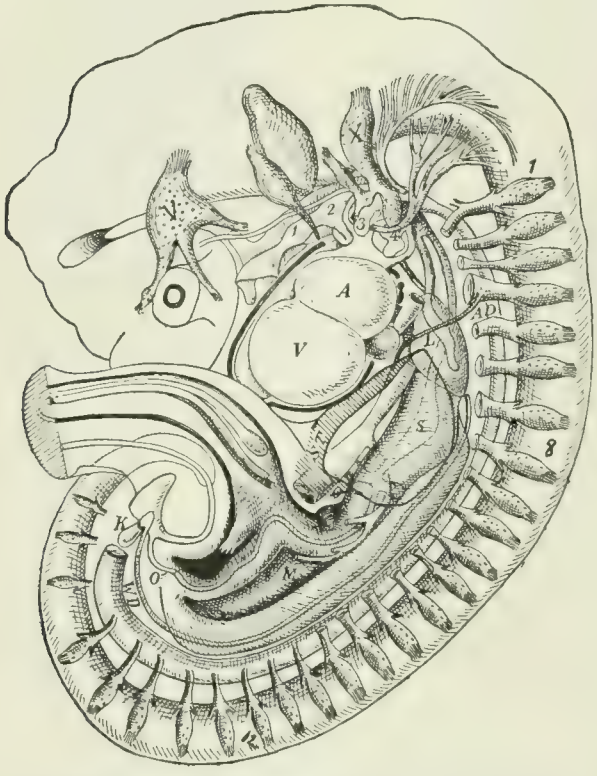


Fig. 2382.—Reconstruction of Embryo No. II., Johns Hopkins University Collection. (Enlarged 17 times.) *V* and *X*, Fifth and tenth cranial nerves; 1, 2, 3, and 4, cast of the branchial pockets; 1 and 8, first and eighth cervical nerves, from the fourth the phrenic arises; 12, twelfth dorsal nerve; *A*, auricle; *V*, ventricle; *L*, lung; *S*, stomach; *P*, pancreas; *W D*, Wolffian body; *K*, kidney; *M*, mesentery; *S T*, septum transversum; *O*, openings which communicate with the peritoneal cavity of the opposite side. The black line around the heart marks the pericardial cavity. (After Mall.)

During the first part of the week the embryo becomes very much flexed, so much so that the head and tail nearly touch. The brain vesicles are better developed, as are also the gill clefts and arches, the eyes, ears, and nasal pits. The heart, which is much enlarged, lies in the cervical region, near the mouth, and produces with the liver, which is now of considerable size, a large ventral bulge. The simple tubular heart with its single cavity is rapidly changing into a complicated four-chambered structure with imperfect partitions. By the end of the fourth week (see Fig. 2382) the anterior enlarged portion of the head has become bent at right angles to the main axis of the body. From the first gill arch a maxillary process is developing which will ultimately form a portion of the upper jaw. From the main portion of the arch will form the lower jaw. The limb buds have increased in size. The arm bud projects from the cervical region and the leg bud from the lumbar region. The yolk sac is very small and the amniotic sac is much enlarged. During the early part of the fourth week the intestinal tube, composed of its several characteristic segments, lies in the sagittal plane attached to the dorsal wall of the body cavity by the straight primitive mesentery. Toward the last of the week rapid growth takes place, the intestine lengthens, and becomes coiled and twisted.

The nerves have begun to grow from the medullary tube or central nervous system into the mesenchyme. Plexuses are forming, but the nerves are not attached to their end-organs. There are now thirty-eight primitive segments or myotomes which have been formed from the mesenchyme lateral to the spinal axis. Muscle fibers are beginning to differentiate from the cells of these segments. Their ventral ends have begun to grow into the primitive abdominal wall formed by the growing around of the amnion. Condensed mesenchyme marks portions of the vertebral column. In the arm bud the mesenchyme is beginning to differentiate to form the skeletal core of condensed mesenchyme. The Wolffian ridge has increased in size and the Müllerian duct is now formed and runs parallel with the Wolffian duct. A diverticulum from the lower end of the Wolffian duct near the cloaca indicates the beginning of the permanent kidney and its duct, the ureter. On the Wolffian ridges are also seen the first traces of the sexual glands, but they are indifferent in type, and not until the fifth week can sex be determined by microscopical examination.

By the middle of the fifth week the embryo is nine millimeters in length. The amniotic sac is now so much enlarged that it is everywhere in contact with the chorion. A true umbilical cord of some length has developed by the enclosure of the entire belly stalk and yolk stalk within a tubular prolongation of the embryonic ectoderm and somatic mesoderm of the embryo. The embryonic ectoderm at the end of the

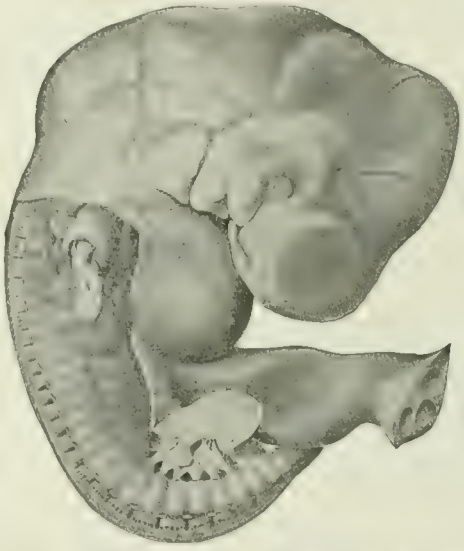


Fig. 2383.—Lateral View of a Human Embryo 9 mm. in Length and About Four and One-half Weeks Old. No. CLXIII. Johns Hopkins University Collection. (Enlarged about 8 diameters.) The areas from which the skin has been removed are drawn from reconstructions, the remaining portions from excellent photographs. The myotomes are growing into the body wall. Portions of the premuscle masses of the arm are seen and also the preskeletal tissue of the arm and leg with the beginnings of the lumbar sacral plexuses. (After Bardeen and Lewis.)

cord is continuous with the extra embryonic ectoderm of the amnion, and the somatic mesoderm with that of the amnion, which is in contact with that of the chorion. So, strictly speaking, the umbilical cord is a portion of the embryo, the amnion having been carried farther and farther from the umbilicus by extension of the embryonic ectoderm. The head is as large as the rest of the body, and bent at right angles

to it. Its large size is due to the rapid growth of the brain. The three primary divisions of the brain are more marked and bent upon each other. From the forebrain the cerebral hemispheres have begun to grow. The spinal cord forms a thick-walled tube of nervous tissue. The various cranial and spinal nerves now extend some distance into the body and the motor nerves of the head and shoulder reach the premuscle masses. The rami communicantes are already present at this stage and connect with the sympathetic cord. The latter forms a continuous column of cells in front of the vertebræ, and has not as yet separated into ganglia. The sympathetic nerve cells have reached this position by migration from the ganglia of the dorsal roots.

At about this time the suprarenals commence their development and are found, at the beginning of the third month, occupying their characteristic position as a cap fitted over the head of the kidney. They rapidly acquire a very large size and at birth have their permanent volume. There is no developmental relation between the suprarenals and the kidney. The suprarenals are probably derived partially from the mesonephros and partially from the sympathetic nervous system, the latter giving rise to the medullary portion and the former to the cortical portion.

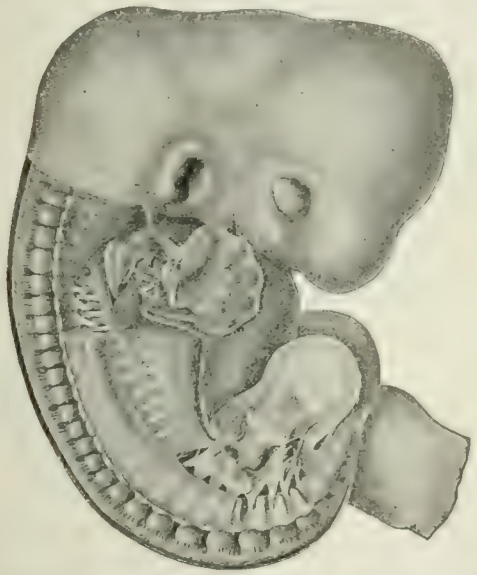


Fig. 2384.—Lateral View of a Human Embryo 11 mm. in Length and About Five Weeks Old. No. CIX., Johns Hopkins University Collection. (Enlarged about 7 diameters.) The dissected area was drawn from a reconstruction. (After Bardeen and Lewis.)

The gill clefts and arches are undergoing marked changes. From the first arch the upper and lower jaws are developing. From the first cleft the external auditory canal and ear drum are forming, and from the pharyngeal portion of the cleft the Eustachian tube and middle ear. The malleus and incus of the ear arise from the dorsal portion of the cartilage of the first gill arch, and from its ventral portion Meckel's cartilage. From the second arch are forming the stapes, styloid process, and the hyoid apparatus, to which later the tongue muscles become attached. The remaining arches and clefts are beginning to disappear by sinking into the depth of the neck, remaining connected with the surface, however, by a deep sinus, the so-called cervical sinus. Occasionally one may persist to adult life as a sinus or cyst. The arm and leg are enlarged and show two segments (see Fig. 2383). The skeletal system consists of a condensed mesenchymal tissue and precartilage. The premuscle masses of the head and arm are differentiating from the mesenchyme. Those of the trunk arising from the myotomes contain muscle fibers and are more advanced, while those of the limbs appear to develop *in situ* about the preskeletal mesenchyme, and show no fibrillation. The heart still lies close to the mouth in the neck region. It is much changed in shape and is imperfectly four-chambered. The truncus arteriosus is undergoing division into two tubes by the formation of the aortic septum.

The modification of the primary arterial system is progressing rapidly. The main portions of the first two arches have disappeared, giving rise with the third arch to the common carotids and their branches. From the last arch the pulmonary arteries are developing, and from the fourth, which seems to be a combination of the fourth and fifth, develop the large aortic arch on the left side and innominate and subclavian on the right side. The latter, however, still retains its connection with the dorsal aorta, giving a condition found in reptiles. The important connection of the last arch on the left side with the aorta remains of large size, and that portion of it between the pulmonary artery and the aorta forms the ductus arteriosus, a very important fetal structure, as it enables the venous blood from the right side of the heart to pass into the aorta without going through the lungs. The growth of the liver has also been an important factor in bringing about modifications in the venous system. With the diminution of the umbilical vesicle the extra embryonic portion of the omphalo-mesenterics disappears, but the embryonic portions of the two veins form the portal system. Of the two umbilical veins, the left persists entire, to form the single umbilical vein of the embryo and cord. The right umbilical vein degenerates into an unimportant vein. The presence of the liver has also modified the proximal ends of the umbilical veins. The left one becomes divided into a capillary net, which again collects into a short vein that opens into the sinus venosus. The development of the ductus venosus soon forms a channel for most of the blood carried by the umbilical vein. The proximal portion of the inferior vena cava is developed as a new structure. The distal end of this unites with the right inferior cardinal in the region where the renal arteries arise; and the caudal continuation of the cardinal from this point of union becomes the inferior portion of the vena cava. The remaining portions of the two cardinals form the azygos veins. A cross anastomosis develops from the left jugular to the right jugular, and from the common stem thus formed develops the superior vena cava. The proximal portion of the ductus Cuvieri on the left side then loses its connection with the jugular and becomes the coronary sinus of the heart.

By the time the embryo is five weeks old it has attained a length of eleven millimeters (see Fig. 2384). The head is still very large and bent at right angles to the main axis of the body. The maxillary and nasal processes, which fuse at a later stage to form the upper jaw, are now more marked and approaching each other. The external nares are nearing the middle line. The external ear is represented by several small protuberances about the first cleft. The general body musculature is well advanced and has its nerve supply. The ribs and the muscles of the thorax and abdomen have grown some distance into the thin membrane, membrana reuniens, which in early stages constitutes the ventral body wall. The limbs are much enlarged and contain a skeletal core of cartilage surrounded by the developing muscles. The arm keeps about two weeks in advance of the leg in its internal differentiation. The vertebral column and ribs are formed partially in cartilage. The fourth pair of the aortic arches still persists entire and the others are modified in various ways to form the larger arteries in this region. The liver has been increasing

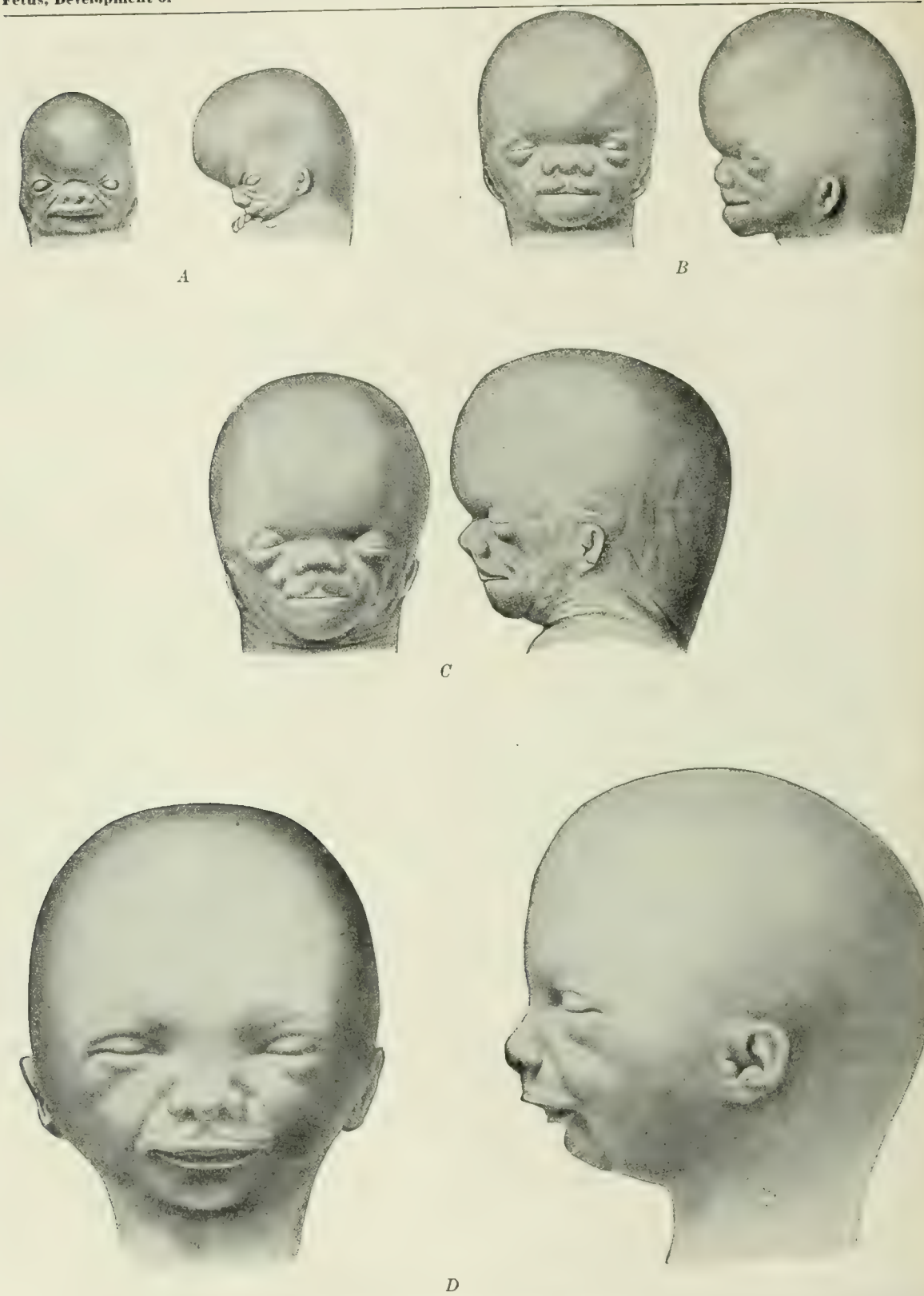


FIG. 2385.—Showing the Development of the Fetal Face and Head. (After Retzius from Broman.) *A*, Fetus 25 mm. long (×2 dia.); *B*, fetus 42.5 mm. long (×2 dia.); *C*, fetus 52 mm. long (×2 dia.); *D*, fetus 117 mm. long (×1.5 dia.).

rapidly in size, and in this embryo as in the preceding stage forms with the heart most of the large projecting abdomen and thorax. The allantois forms a long narrow tube extending from the hindgut into the umbilical cord as far as the chorion. At a later stage the umbilical portion becomes obliterated, while the portion near the hindgut enlarges into the bladder.

During the fifth week the esophagus elongates and the stomach acquires its characteristic form, as well as an obliquely transverse position, its former left side becoming directed anteriorly and upward, and its former right side looking backward and downward. This explains the distribution of the left vagus nerve to the front of the stomach and the right to the back; for, before the twisting of the stomach began, these nerves had already reached the stomach. The connection of the yolk stalk or vitelline duct with the intestinal canal rapidly becomes less marked, and by the end of this week only a small duct attaches the yolk sac to the intestine.

During the last part of the embryonal stage and the first part of the fetal stage there are very important shiftings or migrations of various organs in the body. That of the heart and diaphragm from the cervical

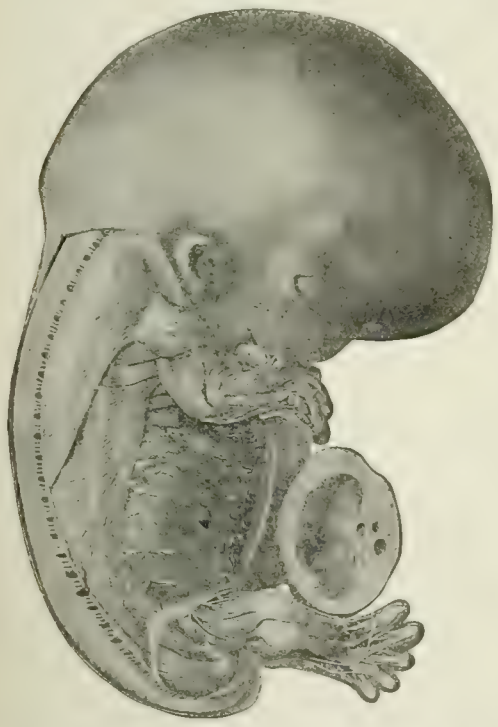


Fig. 2386.—Drawing from a Reconstruction of a Human Embryo 20 mm. in Length and About Seven Weeks Old. No. XXII., Johns Hopkins University Collection. (Enlarged about 5 diameters.) The muscular systems of the limbs and body wall are seen to be well developed. (After Bardeen and Lewis.)

region into the thoracic region is of especial interest, as other structures are dragged along with them. The large blood-vessels are pulled downward, and such nerves as the recurrent laryngeals indicate this process. Originally they passed directly from the vagus to the larynx just posterior to the fifth aortic arch, and by the migration of the heart and large blood-vessels they are brought into the position seen in the adult. The diaphagm in its descent obtains muscle tissue and its nerve in the cervical region, and both are then carried down to the lower part of the thorax. The limbs also exhibit a migration, the arm from the cervical to the thoracic region giving the caudal inclination to the brachial plexus, which originally went straight out into the arm without this caudal inclination. The leg likewise migrates. Many individual muscles also take part in this shifting and migrating, such as the trapezius from the upper cervical region and the latissimus dorsi from the lower cervical. The path of the nerve from its exit at the intervertebral foramen to its point of entrance into the muscle indicates the path the migrating muscle has taken, while the branching within the muscle probably indicates the direction in which the muscle has increased in size.

During the embryonal stage the yolk sac has diminished to an organ of relatively small size and importance, while the central nervous system, with its greatly enlarged anterior end, the brain, giving to the head its great prominence, becomes the predominating feature of the embryo. The head throughout most of this stage is about equal in bulk to the rest of the body of the embryo.

Fetal Stage.—In an embryo seven weeks old and twenty millimeters long the early fetal features are fairly well marked. The head is nearly erect. The fusion of the maxillary and nasal processes is proceeding rapidly to form the upper jaw, and the nasal pits have approached nearer to the median line. Failure of fusion between these processes gives rise to the various forms of cleft palate and harelip. The gradual development of the fetal face and head is best seen by a comparison of Fig. 2385. The arms and legs are much elongated, and show the three segments seen in adults. Fingers and toes are also to be distinguished. Practically every muscle of the body can now be recognized, with its nerve supply (see Fig. 2386). The thoracic and abdominal muscles have pushed farther out into the ventral wall of the body.

By the end of the embryonal stage most of the skeletal elements are laid down either in cartilage or in condensed mesenchyme or connective tissue, and only in the latter part of this period does ossification begin to take place. The membrane or connective-tissue bones are the first ones to ossify—the membranous portion of the mandible and the maxilla in embryos about fifteen millimeters in length. The ossification of the other bones begins as indicated in the following table in the early fetal stage.

The following table gives length of embryo in which ossification begins in the

(A) Membrane Bones of the Head.

Ossa maxillaria	15 mm.
Ossa zygomatica	31 mm.
Ossa frontalia	31 mm.
Ossa parietalia	31 mm.
Ossa palatina	33 mm.
Vomer	33 mm.
Ossa nasalia	42 mm.
Ossa lacrimalia	70 mm.

(B) Cartilaginous Bones of the Head

Incus	190–200 mm.
Stapes	210 mm.
Os ethmoidale	250 mm.
Concha inferior	250–350 mm.

(C) Part Membrane and Part Cartilage Bones

Mandibula (membranous part.)	15 mm.
Os occipitale	31 mm.
Os temporale	31 mm.
Sphenoidale	34 mm.
Malleus (cart. part)	190–200 mm.

(D) Bones of Arm and Shoulder Girdle.

Clavicula	15 mm.
Humerus	18 mm.
Radius	19 mm.
Ulna	24 mm.
Scapula	30 mm.
Distal phalanx thumb	31 mm.

The metacarpals and distal phalanges of the other fingers begin next, then the proximal phalanges and

lastly the middle row, that of the little finger not ossifying until the embryo is 120 millimeters long. The carpals do not ossify until after birth.

(E) Bones of Leg and Pelvis.

Femur	18 mm.
Tibia	19 mm.
Fibula	30 mm.
Os ilei	31 mm.
Os ischii	150 mm.
Os pubis	190 mm.
Distal phalanx big toe	35 mm.
Second metatarsal	35 mm.

The remaining metatarsals and phalanges follow in about the same order as in the hand, the middle phalanx of the little toe not ossifying until the eighth or ninth month; calcaneus, sixth month; talus, sixth month; cuboideum, about birth; the other tarsal bones after birth.

Ribs (Nos. 5–7)	30 mm.
Vertebræ	33–34 mm.

Sternum (variable) fourth to fifth month.

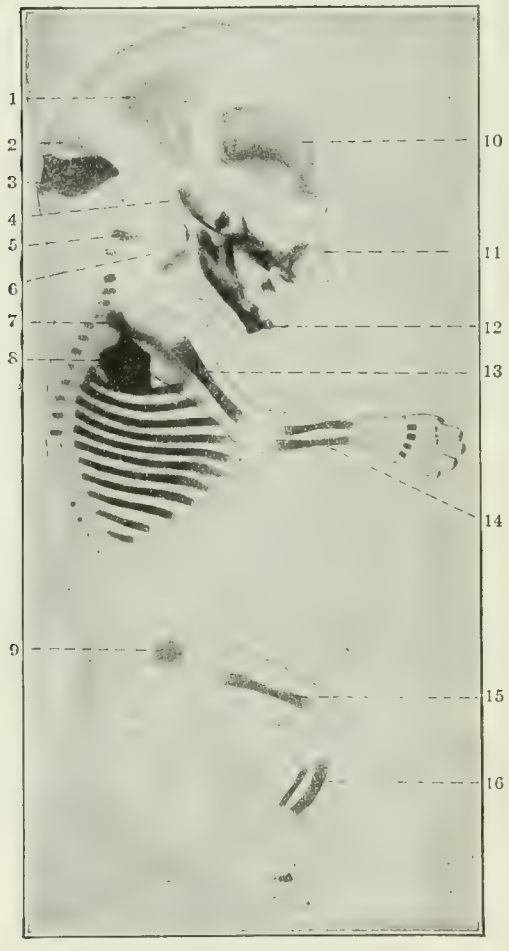
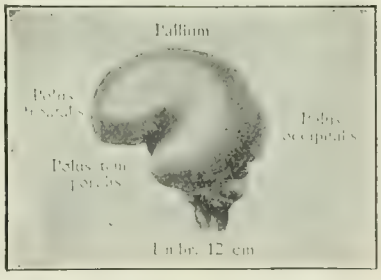


Fig. 2387.—The Bony Skeleton of an Embryo about 70 mm. in Length, × 2 dia (Broman.)

1. Parietal; 2, squama superior and 3, squama inferior of the occipital; 4, temporal; 5, occipital; 6, annulus tympanicus; 7, clavicle; 8, scapula; 9, ilium; 10, frontal; 11, nasal; 12, mandible; 13, humerus; 14, ulna; 15, femur; 16, tibia.

In a fifteen-millimeter embryo the ends of the upper seven ribs have fused on either side to form the two halves of the sternal anlagen. The sternal anlagen lie first in the lateral wall of the body. They gradually come together and fuse in the median line. This process is usually complete in a thirty-millimeter embryo. The progress of ossification during the early fetal stage is seen in Fig. 2387.

Before the fetal stage begins the telenceph-



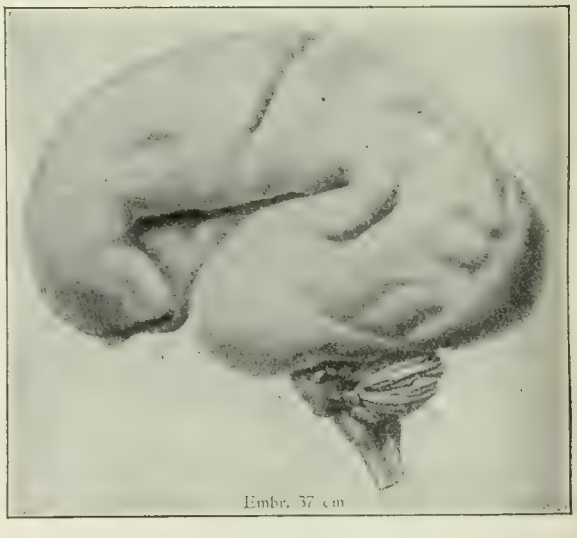
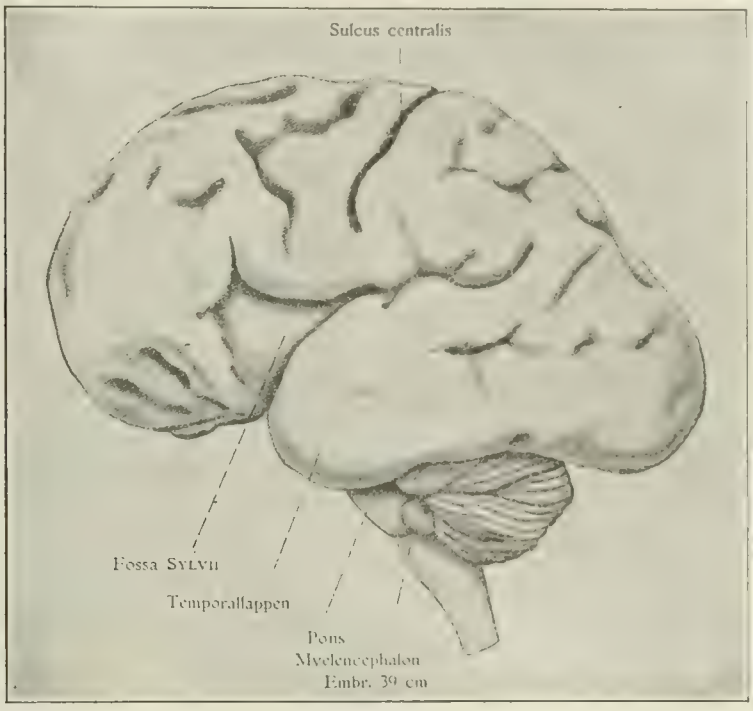


Fig. 2388.—Left Lateral Aspect of the Embryonis Brain, natural size (After G. Retzius from Broman.)

alon or cerebrum constitutes a comparatively small portion of the brain. The thalamic portion of the diencephalon, the mesencephalon or midbrain, the metencephalon or pons and cerebellum, and the myelencephalon or medulla form by far the largest portion. The cerebrum has already begun to grow out from the forebrain in a ten-millimeter embryo



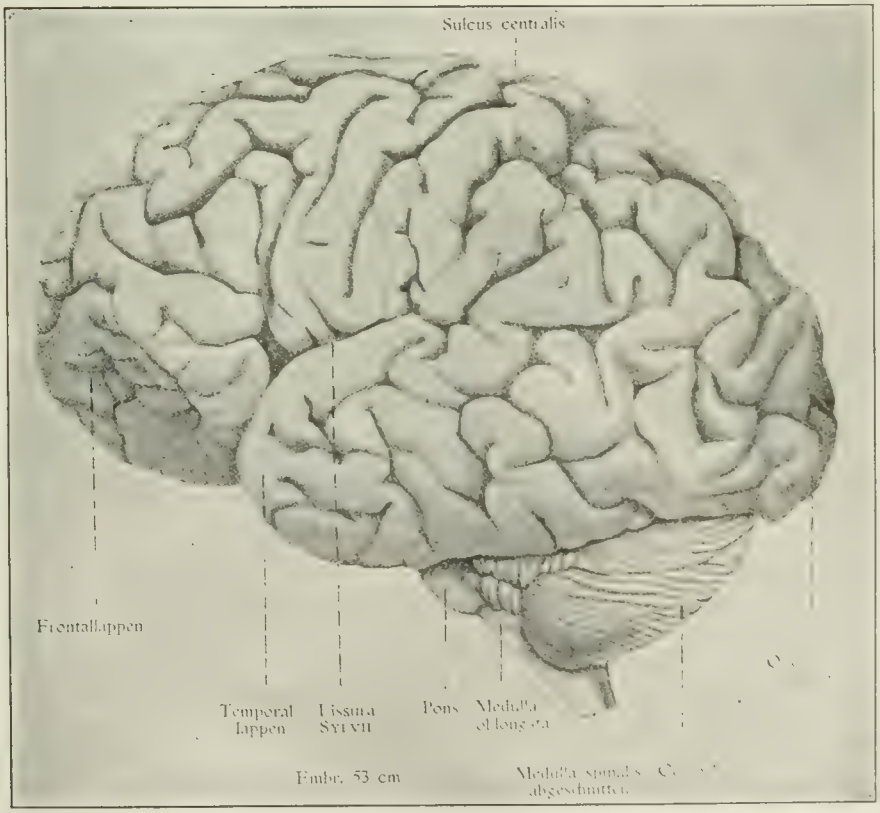


Fig. 2389.—Left Lateral Aspect of the Embryonic Brain, natural size. (After G. Retzius from Broman.

and begins to predominate in the fetal stage. In a fetus 120 millimeters long it constitutes the greater portion of the brain. The increase in the size of the brain and the formation of the fissures and sulci can be followed in Figs. 2388 and 2389.

By the end of the second month the permanent kidney is fairly well formed and the Wolffian body, which so far in the life of the embryo has performed the function of an excretory organ, begins to lose its importance. All but the middle portion, which later forms the sexual gland, atrophies. Its duct in the male forms the vas deferens, in the female degenerates, while in the female the Müllerian ducts form the Fallopian tubes and uterus, and in the male degenerate. Thus by the end of the second month most of the organs which are found in the adult are formed. The main processes which now take place until birth are the growth and shifting about of these organs.

The *third month* establishes the human form, although the head still unduly predominates. The limbs have acquired their definite shape, and the imperfect nails are present on both fingers and toes. The external organs of generation become definitely differentiated, although they make their appearance several weeks earlier.

In the female the genital tubercle remains much less developed to form the clitoris. The genital furrow remains open to form the vestibule and the genital swellings the labia majora. The prepuce and labia minora developing from the genital folds lie at either side of the genital sinus. The genital swellings in the male when they develop into the scrotum have layers identical with those of the abdominal wall, as seen in the following scheme:

Abdominal Walls.	*Scrotum.*
Integument.	Integument.
Superficial fascia.	Dartos.
External oblique muscle.	Intercolumnar fascia.
Internal oblique muscle.	Cremasteric.
Transversalis muscle.	Infundibuliform fascia.
Peritoneum.	Tunica vaginalis.

The tunica vaginalis lines the sac, communicating above with the peritoneal cavity; and into this sac later the testicle descends. The anterior end of the ureter now reaches the neighborhood of the suprarenal where it ends in the kidney, which consists of about eighteen lobes, one for each group of tubules connected with the ureter. This lobulation persists until after birth. The suprarenals now fit cap-like over the anterior end of the kidney. At the end of the month the fetus weighs about 120 grams (3¼ ounces), and measures about five centimeters (2 inches) in length.

During the *fourth month* hairs devoid of pigment appear on the scalp and other parts of the body, which is now covered with firmer skin of a rosy hue. The eye-lids, nostrils, and lips are closed. The anus opens, and the coils of intestine, which before extended into the umbilical cord, now lie entirely within the abdominal cavity. The point of emergence of the umbilical cord lies low down close to the pubes. The head forms about one-fourth of the entire body. The bones of the skull while ossifying are still widely separated. The sexual distinctions of the external genital organs are well defined. By the end of this month the fetus weighs about 230 grams (7½ ounces), and measures about ten centimeters (4½ inches) in length.

During the *fifth month* the lower extremities become longer than the arms, nails are well formed, and hairs are more plentiful, but devoid of color. The fetal movements are distinctly felt by the mother. The sudoriparous glands arise during this month as solid cylindrical outgrowths from the primary ridges of the epidermis into the dermis. Later they become coiled and a lumen appears. The heart and liver share with the head in the undue preponderance which these parts present. At the end of this month the fetus measures twenty centimeters (8 inches) in length, and weighs about 500 grams (1 pound).

During the *sixth month* the surface presents many wrinkles and is of a dirty reddish hue; the sebaceous coating, the vernix caseosa, begins to appear. This whitish substance is composed of shed surface epithelium, mingled with the secretions of the sebaceous glands; its primary function seems to be the protection of the integument from maceration by the amniotic fluid. The eyebrows and eyelashes begin to grow. The length of the fetus by the end of this month is about thirty centimeters (12 inches), and its weight about 1,000 grams (2 pounds).

The Seventh Month.—The formation of fat causes an appearance of greater plumpness, although the surface is still somewhat wrinkled. The hairs are longer, about five millimeters in length. The eyelids are now permanently open. The liver is still relatively large; the testicles have descended as far as, or even into, the inguinal canals. Children born at the end of this month may live. The fetus measures at the end of this period about thirty-seven centimeters long (15 inches), and weighs about 1,500 grams (3 pounds).

The Eighth Month.—This and the ninth month complete the fetal period. The chief changes are great increase in weight, as by the end of the eighth month the fetus weighs from 2 to 2.5 kilograms (4 to 5 pounds) and measures about forty-two centimeters in length. The scalp is well supplied with hair, and the finger nails almost reach the finger tips. The lanugo or embryonal down begins to disappear. The subcutaneous fat has increased considerably, giving a more rounded form to the body.

The Ninth Month.—During this month there is a relatively large increase in weight, from 2 to 2.5 kilograms to about 3 or 3.5 kilograms (6 to 7 pounds), while the increase in length is only from about 42 to 50 centimeters (20 inches). The skin is less highly colored and the lanugo has almost entirely disappeared. The testicles have descended into the scrotum; in the female the labia majora are in contact. Centers of ossification usually appear in the epiphysis at the lower end of the femur, and often in the upper epiphyses of the tibia and humerus.

Warren Harmon Lewis.

Fetus, Diseases of the.—Seventeen per cent. of infant deaths during the first year are due to congenital causes. Thirty-three per cent. of these occur during the first month. We shall consider this subject in the following manner:

(A) The influence of acute infectious diseases of the mother upon the fetus.

(B) The influence of chronic diseases, infectious and non-infectious, of the mother upon the fetus.

(C) Acute non-infectious poisoning of the fetus from (*a*) chloroform, (*b*) acute toxemias of the mother, of the convulsive and non-convulsive types.

(D) Diseases due, in part at least, to errors in development: (*a*) congenital stenosis of the pylorus; (*b*) hemorrhagic diseases of the new-born; (*c*) congenital goiter; (*d*) fetal endocarditis; (*e*) fetal nephritis; (*f*) diseases of the nervous system.

Influence of Acute Infectious Diseases of the Mother.—*Pneumonia.*—The maternal mortality in pneumonia is very high. This is due, in part, to the disease itself, and in part to the great tendency to abortion or to premature labor. Fetal pneumonia may develop but this is of rare occurrence. The infection with the pneumococcus, in the presence of an active pneumonia in the mother, usually manifests itself as a general infection. The pneumococcus seems to traverse the placenta without difficulty, although it is doubtful whether or not this can take place through an undamaged placenta. The writer is inclined to believe that such is rarely the case

and that some portion of the placenta, or that certain groups of cells, must be previously altered—in this instance, by the toxins of the disease—before the actual passage of the organisms from mother to child. The prognosis in fetal pneumonia infection is thoroughly bad. Of those infants that escape intrauterine death and that are born prematurely, the vast majority meet with an early death.

Influenza.—The effect upon the fetus of maternal influenza depends entirely upon the virulence of the attack. The simple cases have little or no effect; the severe cases are responsible for a high percentage of abortions and premature labors. The fetal death rate is in part, dependent upon prematurity, in part upon the toxemia of the mother, and only in rare instances is it due to an *active invasion* of the *bacillus.*

Typhoid Fever.—Typhoid fever is always a serious complication of pregnancy. It markedly increases the fetal mortality and it results in abortion or prematurity, in fifty to seventy per cent. of the cases. This early interruption of pregnancy is due in part to the temperature, in part to the toxemia, and in part to the death of the fetus. Many of those born alive of typhoid mothers, readily succumb in the early weeks of life. P. Ernst, Morse, and others such as Chantemese, Vidal, Frascani, and Remlinger have shown that undoubtedly the bacillus of typhoid can pass from mother to child through the placenta, but it is a question, here as in other bacterial infections, whether or not this can take place through normal placental tissue.

The study of typhoid fetuses has shown conclusively that the intestinal lesions so typical of typhoid fever are rarely, if ever, apparent at this stage of life. The disease, on the other hand, assumes the form of pure typhoidal sepsis in the majority of cases. The organisms are found most often in the spleen. The Widal reaction is not infrequently positive, but is as a rule more or less uncertain. Finally, it is possible for a pregnant woman to have typhoid fever without infection of the offspring.

Ballantyne, A. Charrin,[1] Charrin and Nattau-Larrier,[2] Charrin, Guillemonat, Levaditi[3] have called especial attention to the possible late results that may develop in infants who have survived an intrauterine typhoid. These changes are probably due (1) to active typhoidal poison and (2) to toxins transmitted to the fetus over a considerable period of time. Such changes involve a tendency to bronchopneumonia, gastroenteric disturbances, marasmus, and, rarely, lessened intellectuality (J. E. Corbin,[4] W. Osler[5]).

Diphtheria.—Diphtheria during pregnancy is not common. In the cases in which it does occur, danger to the fetus is present only in the severe grades of intoxication. Although but few careful clinical observations have, so far, been made in this line, in human subjects, Schmidlechner has obtained definite results in animal experimentation. He inoculated nineteen animals with "diphtheria toxin." From his studies on these animals, he deduced the following: (1) A portion of the diphtheria toxin is transferred to the fetus, and causes in it similar changes as found in the mother. (2) The intensity of these changes depends upon the quantity of toxin injected in the mother. (3) The changes develop quickly in the fetus (4) The mode of transmission is through the placenta. (5) Most of the toxin in the fetal circulation remains for a long time unchanged, and the injection of this blood into another animal causes the same changes as were present in the first mother and child.

Scarlet Fever.—Scarlet fever is not uncommon in pregnancy; abortion may or may not take place. It has been believed that the pregnant woman possesses a certain immunity to the disease. This viewpoint, quoting Williams, was held by such men as Braxton-Hicks and Olshausen, who supported this theory on the ground that scarlet fever is seen much less frequently during pregnancy than in the puerperium. It is probable, however, that a large percentage of so-called puerperal cases were not examples of true scarlet fever but were examples of puerperal sepsis.

It is well known to-day that a considerable number of obstetrical patients suffering from one of these severe types of infection, develop rashes resembling scarlet fever. The prognosis, when the fetus is infected, is uncertain. We know that it is possible for a healthy child to be born despite an active scarlet fever in the mother.

Numerous authors believe that children born of mothers who have, or have had, scarlet fever during pregnancy, develop immunity to the disease. While this may be true in certain cases, we believe that there are many exceptions, for several writers have reported instances in which healthy children, who have been born of mothers with scarlet fever, later contracted it through the nursing.

Inasmuch, then, as considerable uncertainty still exists in this regard, a conservative viewpoint, in the management of such children who are born alive, should be followed.

Measles.—While measles in itself is not a dangerous disease, still, when it occurs during pregnancy it is very likely to cause abortion or premature delivery. A few cases of undoubted intrauterine measles have been reported in the literature, but such cases are rare.

Smallpox.—Smallpox complicating pregnancy has naturally a more serious prognosis than at other times; it exerts a deleterious influence upon the offspring, frequently causing the interruption of the pregnancy. This interruption of pregnancy may be due to the direct transmission of the disease to the fetus, to the high temperature, or to hemorrhagic changes in the placenta. The occurrence of intrauterine smallpox has been definitely established, as children are occasionally born in the eruptive stage of the disease and with distinct pock-marks. On the other hand, in the case of women suffering from an early active variola who abort at an early stage of the disease, it is possible for the infants to be born either dead or alive without any signs of the disease. The development of intrauterine immunity is now believed to be most improbable.

Gonorrhea.—Gonorrhea in pregnant women should be considered as a serious complication both for mother and child. In many instances the organisms invade the decidua giving rise to inflammatory conditions which lead to abortion or premature labor. Gonococci have been demonstrated in decidual endometritis by Newman, Maslovski, Williams, and others.

In the study made on this subject in 1906 by James A. Harrar and Ralph W. Lobenstine it was found "that gonorrhea in the mother in the later months of pregnancy is not only a cause of a large number of premature births, but that it has decided influence in lowering the average birth weight at term; and this low average birth weight is largely due to the local effects of the disease, vitiating the normal nutrition of the fetus."

Influence of Chronic Diseases of the Mother.—*Tuberculosis.*[6]—We are still ignorant of the exact part played by heredity in the production of tuberculosis. In the attempt to answer this important and interesting question, two theories have been advanced: (1) The theory of an hereditary predisposition; (2) the theory of direct bacterial infection *in utero.* In support of the first theory: (1) Direct bacterial transmission is far too unusual to account for the frequency of the disease in the young. (2) A predisposition to the disease may be derived almost as frequently from the father as from the mother; while in the case of the true congenital transmission,

no authentic case of direct transmission from the father is on record. (3) The predisposition may be handed down from a parent, grandparent, etc., having only a mild form of the disease; while in those cases in which direct bacterial infection takes place, the parent (the mother) suffers usually (not always according to Schmorl) from a severe type of the disease—most frequently from a general miliary tuberculosis.

In support of the second theory: The first undoubted case of congenital tuberculosis was described by Johne in 1885, and occurred in a (calf) fetus of eight months, found in the uterine cavity of a cow which died of phthisis, the uterus and placenta being normal.

Since then numerous cases have been described by other veterinaries, until in 1898 more than sixty cases of calves with congenital tuberculosis had been reported, and Klapp estimated that 2.63 per cent. of all calves born of tuberculous cows are tuberculous.

Human cases of congenital tuberculosis are much less frequent, Schmorl and Birch-Hirschfeld being the first to describe the case of a seven-months fetus born of a tuberculous mother and showing tubercle bacilli in its liver and the placenta, no histological changes of tuberculosis being present.

Sabouraud was the first to describe a well authenticated case of congenital tuberculosis in which miliary tubercles were found in the liver and the spleen of the infant. Other cases have been reported since the year 1825, but in the absence of convincing microscopical examinations, these must remain doubtful.

The literature has been critically reviewed more recently by Warthin, Cowie, and Wollstein, whose stricter classification has served to separate the undoubted from the doubtful cases, the criteria required being "the presence of characteristic anatomical changes and of tubercle bacilli, the development of the lesions within such a short time after birth as to preclude the possibility of extrauterine infection, and the exclusion of syphilis." From this point of view the undoubted cases of congenital tuberculosis have been reduced to a mere handful. Not a single indisputable case of direct bacterial infection from the father is on record; even though experiments have proven, beyond a doubt, that the semen may contain tubercle bacilli in advanced general tuberculosis, or severe tuberculosis of the testes.

The infection is transmitted in all cases through the placenta or decidua basalis, from the maternal blood (although the ovary may be the seat of the tuberculosis, it has not been positively demonstrated that direct infection has taken place through an infected ovum). The placenta shows, in all cases, tuberculous changes; but the degree of infection of the child does not necessarily depend upon the degree of those changes.

Character of the Involvement of the Child.—(1) There may be bacterial infection without definite lesions. (2) There may be both bacterial changes and tubercle bacilli.

Schmorl has described placental tuberculosis as occurring in four forms, dependent upon the localization of the tubercle bacilli; on the periphery of the villi, when the tubercles form in the intervillous spaces; in the interior (stroma) of the villi; in the basal decidua; in the chorion, involving the amnion as well. The first form is the most frequent one, and occurs especially in placentæ which are fully formed; the third variety, on the other hand, occurs in the early months of pregnancy. The second variety is very rare, as a primary placental lesion (Schmorl having found it but once), though, as in our case, tubercles in the substance of the villi often occur secondarily to their formation in the intervillous spaces. The rarity of this form of primary placental tuberculosis would argue against the villus involvement while the syncytium remains normal. The case described by Wollstein and Lobenstine[6] illustrates the intervillous and chorionic localization of tubercle bacilli, with secondary involvement of the villous stroma. Schmorl describes one case in which the tuberculous area in the chorion had perforated the amnion and tubercle bacilli were found on the surface of that membrane. Thus, says Schmorl, there is the possibility of gastrointestinal infection of the fetus by means of the tubercle bacilli in the liquor amnii.

Of late a number of the best foreign observers have been disposed to believe that a good many of the so-called early postnatal infections have in reality been cases of intrauterine infection. Certainly in the light of the recent work on tuberculosis of the placenta, etc., this possibility should be carefully weighed. Francine contends that the tubercle bacillus may lie dormant in the lymphatics of the new-born and not become active until some weeks after birth. Today such men as Jung, Schmorl, and Baumgarten cling strongly to the belief that not infrequently tubercle bacilli are to be found in the blood of the new-born. Even if we believe that the villi must be damaged in order to allow the passage of tubercle bacilli, we may still readily appreciate how this injury can take place during the height of the labor.

Schmorl, Schlimpert, Norak, Ranzel and others consider it quite possible and probable that during hard uterine contractions tubercle bacilli are forced from the placenta into the fetal circulation.

After conception has taken place, it is but reasonable to suppose that abortions are somewhat more common than in non-tuberculous cases. This is partly due to the cough, partly to the vomiting, or to the temperature; it may be due to an endometritis or to a beginning tuberculosis of the decidua. We find, moreover, that the tendency to premature labor is even greater than the tendency to miscarry. This is particularly seen in tuberculosis of the larynx. When the disease is stationary or when the pulmonary condition is but moderately active, it is possible for the tuberculous woman to bring forth an apparently well-nourished, active, and healthy child. This fact is but seldom noted in the severer grades of tuberculosis.

According to Weinberg, 67.9 per cent. of infants of tuberculous parents, whose mothers died within one year after labor, died likewise within the first year of life, as against a normal death rate of twenty-five per cent. Of fifty-seven infants born alive, whose mothers died within four weeks of labor, 78.8 died within the first year. If to these early cases we add the vast army of children that later develop the disease from contact with the tuberculous parent, we will appreciate the great toll on health and life, due to faulty inheritance and faulty surroundings.[7]

Malaria.—In this climate malaria contracted during pregnancy has, in the majority of cases, little influence upon the course of the latter. This statement applies merely to the more usual types of the disease. In the severe grades, it is unquestionably true that both abortion and premature labor occur not infrequently; premature labor as a result of the malarial infection is far more common than abortion. This fact depends very considerably upon the tendency of the quinine to initiate uterine contractions, although several writers have claimed that the oxytoxic properties of the quinine are apparently in abeyance under these conditions. This belief, in the writer's opinion, should be accepted with great caution. Whether or not the *Plasmodium malariæ* has ever been found in the fetal blood or in the several organs is still a question of wide discussion. There are undoubted cases, however, in the writer's experience as well as in that of numerous other observers, in which the child at birth has given evidence

—either within the first few days of life or at least during the first few weeks—of active malarial infection. A congenital hypertrophy of the spleen is the most constant pathological feature found in the child born of a mother who has recently suffered from active malaria.

Chronic Lead Poisoning.—In pregnant women suffering from chronic lead poisoning abortion occurs in fully sixty per cent. of the cases. Children born alive show a high secondary mortality, exhibit marked tendency to convulsions and instability of the nervous system generally. When both mother and father are affected with plumbism at the time of conception, the intrauterine death rate may reach as high as eighty-five per cent. The metal has been found in the organs of the fetus where it has apparently caused inflammatory changes. By means of experiments on guinea-pigs, lead has been shown to pass from mother to offspring and to be widely distributed in the latter. It has further been proved experimentally to be a strong abortifacient.

In 1860 Constantin Paul from experiments and observations concluded that lead poisoning may, in its effect upon the fetus, act very similarly to syphilis; viz., either the fetus may perish *in utero* or it may, and probably will, suffer after birth (when born alive) from certain dyscrasia resulting from the parental condition. Ballantyne reports the results of eighty-one observations made by Paul on workers in lead factories. These observations were arranged in six series.

In the *first group* he placed women who had had more or less serious signs of plumbism. There were four women in this series who had had fifteen pregnancies, of which ten had ended in abortions, two in premature labor, one in a dead-born infant, one in an infant that died in twenty-four hours, and one in an infant that survived birth.

In the *second group* were placed five women (including the original case referred to above) who had had normal pregnancies prior to their working in lead, but who afterward out of thirty-six new pregnancies had had twenty-six abortions, one premature labor, two dead-births, five infants of whom four died in the first year, and two infants who survived.

In the *third series* is a single case, that of a woman who had ceased to work in the type-foundry; as a worker she was five times pregnant, and had five abortions; after ceasing to work she had one pregnancy, the result of which was a living and healthy infant.

In the *fourth series* were two cases: (1) That of a woman who had ceased to work in the foundry, gave birth to a living infant four years later, and had then returned to work, and had since had one abortion and probably three others; (2) that of a woman who had, on two occasions, ceased to work, and in each interval had had a living (and surviving) infant, and who had thereafter worked continuously and had two abortions.

The *fifth series* was very interesting; it contained seven cases, in which either the husband alone was exposed to lead poisoning, or in which, although both parents were exposed, the husband alone suffered from signs of saturnism. Out of thirty-two pregnancies, there were eleven abortions and one dead-birth, while of the twenty infants born alive, eight died in the first year, four in the second, five in the third, and three survived. The conclusion drawn is that the father as well as the mother may transmit the evil effects of lead poisoning, although in a less grave degree, to the offspring; but to do so he must be suffering from the lead ("en puissance de plomb") at the time of fecundation.

In the *sixth and final* series were the cases where the blue line on the gums was the only sign of plumbism; there were six women in this series, who had twenty-nine pregnancies, among which there were eight abortions, one premature labor, twelve dead infants, and eight living infants; so that, when the effects of the lead on the parent were less marked, the results to the offspring were also less severe. Paul draws the evident conclusion that, while lead poisoning does not prevent fecundation, it very gravely interferes with antenatal life; for, out of a total of one hundred and twenty-three pregnancies, in seventy-three the product was dead before expulsion from the uterus, and thirty-five infants, born alive, died in the first three years of life.

Manifestly it is a grave matter for the fetus when one or both its parents are "en puissance de plomb." In a later article Paul[8] added two other cases to the list, giving a total of one hundred and forty-one pregnancies, ninety-one abortions, dead-births, and premature labors, and thirty-five infants who died in the first three years of life.

Fournier's exclamation regarding syphilis is surely not inapplicable here also: "Quelles statistiques! Quelles horribles tables mortuaires!"

Later, F. Roque[9] ascribed to working in lead, not merely the high infant mortality, but also the frequent occurrence of idiocy, imbecility, and epilepsy.

In 1881, O. Rennert[10] found that, of the children of eleven men working in pottery-glazing, many had certain cranial anomalies. These eleven men suffered from plumbism while the wives showed some signs thereof. Either at birth or soon thereafter, the heads of the infants were, in many instances, peculiarly square-shaped, and increased in size more rapidly than the normal, without, however, the signs of hydrocephalus. There were *no* signs of rachitis. Later these infants showed a tendency to develop convulsions, and of their number, fifty per cent. died (twenty-eight out of fifty-six affected).

"The localization of the effects of the lead upon the brain and cranium is interesting, when taken in conjunction with Porak's experimental results in which the metal was found especially in the nervous system." On the other hand, Legrand and Winter found in a case of their own that the lead was most easily recovered from the liver and spleen.

At the present day, the worst examples of plumbism are found in Hungary in the potteries. In some of the villages, the majority of the workers in the potteries have no children. The children, in other villages, that survive have a tendency to hydrocephalus, meningitis, convulsions, epilepsy. Those that reach adolescence have a peculiarly stunted appearance. Infantilism is common.

At Temerrin, T. Oliver found that in one family seven children had died in convulsions; in another family six children had thus perished.

Dr. George Reid (Rept. Dept. Committee on Dangers Attendant on the Use of Lead) found that, "females who worked in lead before marriage miscarried twice more frequently than the non-lead workers, and that those who worked in lead after marriage miscarried three times more frequently."

Next to syphilis, plumbism destroys and injures more lives than any other agent known. (This is relative of course, depending upon the country in question.)

Chronic Mercurial Poisoning.—In pregnant women who are subject to chronic mercurialism, the tendency to abortion and premature labor is again found to be high. This is directly opposite to the action of mercury in the presence of syphilis and pregnancy. In the latter condition, mercury in large doses not only prevents abortion but is a real life saver. Mercury has been found in the placenta, liquor amnii, and fetus ("in the brain, heart, lungs, liver, kidney, and spleen").

Phosphorism and Arsenicism.—The chief effect of both phosphorus and arsenic upon the fetus when the mother is suffering from chronic poisoning therefrom, consists in the high percentage of interruptions of pregnancy. Lead, arsenic, and phosphorus are widely used to produce criminal abortion, and have been responsible for many deaths.

There is good evidence at hand to warrant the belief that, in certain cases at least, of acute phosphorous poisoning, the lesions of the fetus are identical with those found in the adult under such circumstances, namely, fatty degeneration, disintegration of the parenchyma cells, particularly of the liver and kidneys, ecchymosis, and acute hemorrhages. Phosphorus is, of all the metallic abortifacients, the strongest and is used to a considerable degree for this purpose, despite the tremendous risk involved, among the ignorant classes in certain countries. I have myself observed one such case which resulted in death to both mother and fetus.

Chronic Alcoholism.—The principal action of alcohol upon the fetus is shown in the distressingly high tendency to nervous disorders both of the brain and spinal cord, as well as many other features of degeneracy. It is unquestionably a curse to the offspring. Experimental investigation has proved beyond a doubt that alcohol passes readily from mother to fetus, both in human beings and in animals. This action may be either immediate or remote. During pregnancy it has a tendency to interfere with the normal progress thereof, either by its direct effect opon the fetus, or by means of its action upon the placenta. Aside from the fact that it increases intrauterine mortality, it so influences the resistance of the offspring that many of these die at an early age.

Sullivan[11] found, in an exhaustive study of the subject, that to 120 female inebriates were born 600 children of whom 55.8 per cent. died under two years of age or were still-born.

In thirty-three cases of non-alcoholic women related to the above inebriates, the rate of still-births and early infant mortality was 23.9 per cent. Sullivan further demonstrated that the fetal death rate among alcoholics was progressive in type, thus illustrating the frightful ravages of maternal alcoholism. The earlier the mothers became alcoholics, the higher the infant mortality.

Nicotine Poisoning.—It is a strange fact that, considering the extensive use of tobacco in the world at large, and considering the great number of discussions that have been forthcoming, on fetal and infant mortality and morbidity, so little has been said about the possible pernicious effects of nicotine upon the offspring. Observations made by Drysdale of London, Kostral of Austria, Hurteau of Paris, Omer Bey of Turkey, Tidswell of Khartoum, Torquay, and most recently Woods of Philadelphia are, as yet, not widely known by either medical profession or laymen, but are worthy of the closest scrutiny. Tidswell in his book on the "Tobacco Habit" (London 1912) gives the results of his own close study with regard to the effect of nicotine upon intrauterine life, and upon the infant in the early years.

He strongly believes that habitual smoking of the father, and forced inhalation of tobacco fumes and tobacco dust by the pregnant woman have a markedly deleterious effect upon the offspring, and nicotine may, according to his view-point, as well as that of a few other observers, pass into the placental circulation and thus gradually poison the child.

His chief deduction is that, in the series of cases that he personally studied, the wives of the smokers had twice as many dead fetuses as the wives of the non-smokers. A summary of his results will be found in the following table.

	Class 1. Non-smokers.	Class 2. Smokers.
Birth rate per 1,000	7,368	6,859
Excess of Males	474	.....
Excess of Females	.....	473
Miscarriages	394	1,035
Still-born Infants	210	263
Abnormal Confinements	83.7	132.2
Abscess of Breast	80	263
Mortality among 1,000 living children	153	227

Nicotine, in addition to having been found in the placental circulation, has been isolated from the amniotic fluid. Kostral has made interesting observations in the tobacco factory of Iglan near Vienna concerning the effect of tobacco dust upon expectant mothers and upon their offspring.

"The work girls had frequent disturbances of their health and were frequently pallid and breathless. Among those who were mothers and suckled their infants, there was often inflammation of the breasts, and the milk smelt strongly of tobacco. Besides this, of 506 births which took place among these women in three years, Dr. Kostral found that eleven per cent. were still-births, and 206 infants died soon after birth. One hundred and one of these died of brain disease with convulsions, and 110 died in the first three months of life; 160 in the first six months; and 181 in the first year. It was a curious fact, too, that the major part of these infants died when they were from three to four months old, just when their mothers returned to work, and gave their children breast-milk poisoned with nicotine. These facts are conclusive as to the evil effects of smoking and tobacco dust upon the health of infants, children, and adolescents of both sexes.

We may infer from these facts that pregnant women, and those who are suckling their children, should *not* be exposed to tobacco smoke.

A Turkish Medical man, Dr. Omer Bey, observed that in Turkey "It is not alcoholism that causes injury to health, but tobacco. It kills the individual person, the race, and enervates the country. Nicotinism in my country is what alcoholism is in France, and morphinism is in Eastern Asia. In Turkey, people do not drink, thanks to the abstinence enjoined by the Koran, but they smoke everywhere and forever; it is for this reason that we may conclude that nicotinism is a question more important in my native land than alcoholism."

According to Dr. Woods of Philadelphia, a large percentage of cases of epilepsy in early childhood are the result of tobacco poison in the parents.

Charles G. Pease states that arteriosclerosis has been produced in smaller animals by subjecting them to the continual influence of tobacco poison. He also claims, that chronic toxic congestion of the spinal cord and brain is produced by tobacco.

This short survey should be sufficient to arouse interest in a greatly neglected phase of our social life. The work accomplished so far should stimulate others to further investigation along similar lines.

Should further study substantiate the facts presented above, we shall be able to conclude, and not until then, (1) that nicotine in the parent is a serious cause of intrauterine mortality, (2) that it is a grave cause of early infant mortality; (3) that it is a cause of vitiated vitality in the infant, and a frequent cause of epilepsy.

Chronic Opium Poisoning.—But little work has so far been carried on to determine the effects, upon the fetal development and the fetal constitution, of chronic opium poisoning in the parent.

This subject would seem to offer a wide field for investigation, inasmuch as the use of this drug is far more wide spread than is commonly believed. If only the father uses opium, the effects upon the offspring may not be pronounced in the first generation, but in the second. If both parents smoke opium, or otherwise use it, the *rule* is, according to W. Hecker Park *et al.*, that *no* children are born alive; should, however, any be born alive, these usually do not survive.

The Chinese say that the child of an opium-smoking mother cries incessantly after birth, and cannot live unless opium fumes are, at intervals, blown into its face. If it grows up it is practically sure to become an "opium devil."

Both the physical and mental development of the

fetus is unquestionably affected in the majority of cases of children, whose parents are the victims of the drug.

Syphilis.—Syphilis is the most common cause of fetal death at all stages of pregnancy, but especially in the later months.[12]

Together with gonorrhea it is responsible for over fifty per cent. of spontaneous abortions and premature interruptions of pregnancy. From eighty-five to ninety per cent. of macerated fetuses are infected with syphilis. The exact mode of infection is, in the majority of cases, uncertain. The virus is transmitted in one of the following ways: (*a*) Through an ovum which is itself already infected at the time of conception. (*b*) Through direct infection from the father at the time of conception. This is a common mode of infection. (*c*) Through the placenta. It is still uncertain as to whether or not spirochetæ may pass through the placenta with the latter in an undamaged state. It seems probable that, in most instances in which infection takes place through the placenta, certain changes in the cells must already exist. (*d*) At the time of birth from infected cervical discharge, or from specific lesions in the lower genital tract. (*e*) Finally, the fetus may escape infection entirely, but this is exceedingly rare. When such an occurrence takes place it should be definitely understood that the child has *not* developed immunity (as it was supposed to have according to Profeta's law) but has merely, through a most lucky chance, escaped infection. Such a condition is seen from time to time in instances where the mother may not have been infected with syphilis until late in pregnancy, and in certain cases where active treatment has been given the mother during pregnancy. Again, we know that syphilis is very irregular in its action and that it is entirely possible, although rare, for the mother to be specific and to have spirochetes still present in her body, and yet for the child not to be infected. Under such circumstances the spirochetes are said to be inactive.

Syphilitic fetuses are almost uniformly undersized, with the subcutaneous fat poorly developed; the skin shows eruptions of various kinds but chiefly of a bullous type; there is desquamation over large areas, of epithelium, leaving deep red macerated corium underneath. There may be mucous patches in the mouth and pharynx. The liver is enlarged, harder than normal, being the seat of a hypertrophic cirrhosis, its weight may equal one-tenth or even one-eighth of the whole body and miliary gummata are frequently present; there is a marked increase in the connective tissue surrounding the individual lobules and acini, with considerable round-cell infiltration.

The spleen likewise presents marked interstitial changes and increase in size, so that it frequently weighs two to three times the normal. The pancreas undergoes similar changes. The belly is markedly distended, the peritoneum frequently contains fluid. The lungs are enlarged, pale and barely float when placed in water; they are the seat of a so-called "pneumonia alba," in which the air cells are found filled with cast off epithelium. In other cases, the change consists in an increase in the interstitial tissue between the alveoli by which the latter are compressed but do not become quite impervious to air. (Williams' Obstetrics.)

Osseous System.—"The characteristic sign of syphilis is one which is commonly to be found at the junction of the epiphysis with the diaphysis and the long bones (Wagner's Line). Normally the two are separated by a narrow white, slightly curved line, which represents an area of preliminary calcification; in syphilis, on the other hand, this is converted into an irregular, jagged, yellowish line of increased thickness. The changes at the ends of the long bones are due to osteochondritis, as result of which there is no longer the sharply marked zone of preliminary calcification between the cartilage and the growing bone. The area of bone formation and calcification are found irregularly scattered through the lower portions of the epiphysis giving an irregular appearance to this region. These changes are most pronounced at the lower end of the femur; fairly so at the lower ends of the tibia and radius as shown by Williams and others.

"These changes are extremely characteristic, and their detection justifies one in making a positive diagnosis of syphilis. If intrauterine death occurs, the fetus rapidly undergoes maceration, the skin peeling off on the slightest touch, exposing the underlying discolored corium. Under the influence of syphilis the placenta undergoes definite and characteristic changes. It increases markedly in size, so that, in the later months of pregnancy, its weight may be from one-fourth to one-third the total weight of the fetus, instead of the normal relationship of one to six. Its color is commonly a dull gray, with a fatty or greasy appearance, small gummata are seen from time to time, and infarcts are of frequent occurrence. The chorionic villi lose their ordinary appearance, becoming thickened and club-shaped. There is a noticeable decrease in the stroma cells of the individual villi, so that in some cases they are found to have disappeared entirely. This is due in part to a marked endarteritis, and in part to a great increase in the stroma cells. (Williams.)

Spirochetes have been demonstrated in the placenta, umbilical cord, and in the organs of the fetus. They are most abundant, however, as shown by V. Gräfenberg and Levaditi, in the liver and the umbilical cord. V. Gräfenberg has found them in over ninety per cent. of macerated fetuses studied by him.

The discovery of the Wassermann test for syphilis (or one of the modifications thereof) and the isolation of the particular organism of the disease, have modified many of the prevailing views in regard to syphilis during pregnancy, and in regard to its effect on the child. It is now known that the majority of mothers who bring into the world specific infants, whether alive or dead, are *themselves specific.* This is true, even though they may have had no visible signs of the disease. Colles' law is therefore void and cannot be correct.

Aside from the great destruction of life during the sojourn in the uterus, there is, in addition, a high early infant mortality during the first week, or month, of life. But a comparatively small number of such children reach the years of early adolescence, and this we may regard as a wise provision of nature, for, of those children with a specific inheritance who survive early infancy, the majority show definite abnormalities of development. A syphilitic inheritance predisposes the offspring to hydrocephalus, ependymitis, tuberculosis, and gastrointestinal disturbances. Furthermore, "The vast number and variety of brain and spinal cord affections, optic nerve lesions, etc., that are seen in the new-born, or in very early life, the cases of juvenile paresis, tabes dorsalis, etc., are some of the more obtrusive evidences of what syphilis can do in the offspring; and the forces that operate to produce mental defectives, epileptics and the insane, are directly or indirectly traceable to ancestral taint and are indeed powerful. When both parents are syphilitic the offspring are frequently markedly mentally degenerate and physically anomalous; in these children pronounced sexual perversions are often seen. The likelihood of syphilis of the nervous system in the offspring is enhanced when both parents are infected, the maternal influence being the more potent (S. Philip Goodhart[13]).

"There is a condition known as *specific infantilism* seen in the offspring of syphilitic parents; it appears as a general retardation of both physical and mental development.

"Syphilis, furthermore, plays an important rôle in

the production of idiocy. Recently Dr. C. E. Atwood studied a group of idiots on Randall's Island, N. Y., in conjunction with Dr. Noguchi and Mr. Broufenbrennen of the Rockefeller Institute. Separate tests were made on 204 idiots of various types, and on 100 imbeciles and feeble-minded patients. It was found that 14.7 per cent. of the idiots had inherited syphilis, and that seven per cent. of the other classes were afflicted with the disease. Syphilis, then, is the greatest known destroyer (aside from criminal interference) of intrauterine life. It is transmitted in all its virulence to the offspring and rarely fails of being thus transmitted.

It produces, approximately, ninety per cent. of macerated fetuses, and of the actual syphilitic births at or near term, over ninety per cent. are still-born. The mother reacts positively to the Wassermann test, in from seventy-five to ninety per cent. of the cases, even though the disease *in her* may be latent.

Treatment with mercury during pregnancy has shown, on the whole, very indifferent results. In order to mercurialize the mother and child rapidly and as thoroughly as possible, the intramuscular method of injection with such preparations as the bichloride or the salicylate of mercury is the only safe mode of handling these cases, when mercury alone is used. Salvarsan and neosalvarsan have given excellent results when carefully and wisely used.

Arsenic probably does not predispose to abortion, or premature labor; it rarely, if ever, affects the fetus adversely, but on the contrary has greatly reduced the intrauterine death rate from syphilis.

After reviewing the cases reported in the medical literature, we may safely conclude that with the careful use of arsenic and mercury, beginning early in pregnancy, the intrauterine death rate may be reduced to about twenty per cent., while with the intramuscular injections of mercury alone, beginning early and continued throughout the pregnancy, the death rate will be about forty per cent.

Acute Non-infectious Poisonings of the Fetus.—*From Chloroform Administered to the Mother.*—The use of chloroform as an anesthetic in labor may unquestionably exert a baneful influence upon the fetus. Prolonged anesthesia predisposes to cyanosis, asphyxia, and in numerous cases is responsible for the death of the fetus.

Despite the fact that it has been almost universally used in obstetrical cases, the fact is now recognized that its effect upon the fetus, both immediate and remote, may be decidedly pernicious. The cases of delayed chloroform poisoning are not rare, although the recognition of this condition is often overlooked. Symptoms of delayed poisoning in new-born infants are vomiting, (3) jaundice, delirium, convulsions, and coma. One or all of these symptoms may be present. In another group of cases there may be merely apathy and sudden death.

This condition has been experimentally produced in animals by such men as Lengemann, Ostertag, Stiles, Howland and Whipple, Cragin and Hull. Pathologically there are central necrosis, fatty and parenchymatous degeneration in the liver; congestion, fatty and parenchymatous degeneration in the tubules of the kidney; and a tendency to hemorrhages throughout the body. In the writer's opinion, prolonged chloroform poisoning is responsible for a considerable number of the hemorrhagic conditions of the new-born. In these infants that die as a result of the poisoning, these same degenerations produced experimentally on animals are to be found.

The picture of this condition is such a startling one, and one giving such a high death rate, that chloroform as a prolonged anesthetic should give way to the use of ether.

The Influence upon the Fetus of the Toxemias of Pregnancy.—The toxemias of late pregnancy, whether of the convulsive or non-convulsive types, have a strong influence for evil upon the fetus. The fetal mortality rate in the severe cases is high. In the convulsive type, the severer the intoxication and the greater the delay in the delivery of the mother, the higher the fetal mortality. This mortality is due (1) to placental hemorrhages and infarcts; (2) to the fetal poisoning; (3) to the high temperature in the mother, in certain severe cases; (4) to the chloroform, morphine or hyoscine-scopolamine used during delivery, in the case of infants already weakened by "intoxication"; (5) to severe operative manipulation at birth; (6) prematurity.

A certain small percentage of these cases develop convulsions "*in utero.*" Death under these conditions may give rise to "intrauterine rigor mortis."

Many of the children enter life apparently sound and with care progress entirely satisfactorily; on the other hand—and I will accentuate this observation—a certain number of infants that are born, at or near term, of toxemic mothers, without severe operative interference—and apparently well, *do not thrive.* These infants may lose ground the first two or three days, or they may show nothing abnormal for several days, and then suddenly die or fail very rapidly, with or without the development of convulsions.

These infants may early develop the tendency to hemorrhages. The severe cases are difficult to manage and are usually fatal. In those instances in which chloroform has been used at the labor, late chloroform poisoning, no doubt in certain cases, has a tendency to accentuate the symptoms of the toxemia.

Bar was the first to call attention to the lesions in the fetus brought about by the maternal toxemia. Later Schmidlechner, Bar, Dannay, Schmorl, Dientst, Prutz, Lubarsch, Gottschalk, Ebinger, Dohm, De Lee, Ewing, Stone,[14] Wollstein, the writer, and a few others observed typical cases, showing intense degeneration, with or without hemorrhages. The liver and the kidneys show marked cloudy swelling with at times intense disintegration of the parenchyma cells, with capillary hemorrhages. There may be hemorrhage beneath Glisson's capsule; hemorrhage into the brain, pleural cavity, peritoneal cavity, suprarenal capsules, skin, etc. There may be blood, albumin, casts, leucin, and urobilin in the urine. The picture is a typical one, and one of marked importance.

Diseases Due, in Part at Least, to Errors in Development.—Congenital stenosis of the pylorus.* "(*a*) Pure spasm of the pylorus and pyloric end of the stomach, without any palpable pylorus with peristalsis and explosive vomiting, loss of weight and consequent inanition." The constipation present may be only a relative constipation, that is, some fecal matter passes, or there may be several movements, green and fluid, in twenty-four hours, of a brownish color, or the constipation may be absolute, and on forced movement of the bowels, little or no fecal matter passes.

"(*b*) Pyloric spasm with relative and actual stenosis with slight or marked thickening or hypertrophy of the tissues of the pylorus." In these cases there is vomiting of the explosive type coming on soon after birth and continuing for some time with a palpable pylorus, at first, or subsequent to the onset of the symptoms. The pylorus can be felt to harden at the time of greatest peristalsis of the stomach and to soften after vomiting has occurred. Constipation, complete at first, which after some duration of the disease mitigates, and fecal particles may appear in the stools. There is marked progressive atrophy and inanition.

"(*c*) Congenital hypertrophy of the pylorus with stenosis." These cases, which are only relatively more marked in their symptomatology than those in the

*Although usually classed only under "Diseases of Infants' this condition is likewise correctly considered in the present discussion. The classification of Koplik is presented here, as it is clear and comprehensive.

previous class, give exactly the same symptoms. There is the same spasm of the pylorus as an accompanying symptom; the pylorus can be felt just as in the previous class; the peristalsis is just the same, and the constipation is the same, only possibly more marked.

"When operated on, cases in class three may show much more enlargement and hardening of the pylorus than was manifest before operation. This has given rise to the presumption that they are a distinct entity apart from class two." (Koplik.)

Hemorrhagic Diseases of the New-born (Ritter's Disease, Bühl's Disease, Winckel's Disease, Hemophilia.—Although this group of diseases, primarily, should be considered under "Diseases of Infants" and not under "Diseases of the Fetus" we still feel that etiologically it should be discussed, to a certain extent at least, in the present connection.

Clinically, we find two essential types (according to the period of manifestation), which types may become more or less fused: (*a*) The cases that develop hemorrhages before birth, either before labor or during the latter. (*b*) The cases that manifest the hemorrhagic tendency after birth, anywhere from a few hours thereafter to many days later.

Among the possible constitutional causes are to be found syphilis, alcoholism, antenatal infection, family hemophilia, the toxemia of pregnancy, chloroform. The direct underlying causes that are dependent upon some antenatal factor are: (*a*) endothelial changes in the blood-vessels; (*b*) a disturbance in the balance of the ferments of these cells (Welch); (*c*) a change in the character of the blood; (*d*) superficial congenital ulcers in the gastrointestinal tract (Landon, Winckel, Hecker, Spiegelberg).

Welch, who has performed good work in this connection, believes with some others that the bleeding is *not* due to lessened coagulability of the blood. He states, and very accurately, that the bleeding in these cases must be stopped through some other agency than mere increased clot-formation, as the blood in existing hemorrhagic areas is absorbed, in those cases that recover, without clot-formation.

W. W. Duke has pointed out, that there is frequently a marked diminution in the blood platelets and a lengthening in the time of coagulation. The blood low in platelets is said to clot within normal limits, but the resulting coagulum is not as firm as the normal. The other supposed changes in the character of the blood which favor hemorrhages are excess of antithrombin, lack of thrombokinase, and defective action of prothrombin. Despite the great amount of investigation that has been going on during the past four years, we are still in the dark in regard to the exact processes concerned in any given case of congenital hemorrhagic disease. Unquestionably we shall find an association of several complex factors, all of which must have a direct relationship to the several clinical manifestations. (In the hemorrhages occurring several days after birth, septic infections play an important rôle.) The bleeding may take place in almost any location in the body. The most excessive hemorrhages are found in the brain, beneath the capsule of the liver, into the pleural and peritoneal cavities. I would again call especial attention to these idiopathic, non-traumatic hemorrhages in the brain. They are chiefly subdural or ventricular. A child with this hemorrhagic predisposition, from whatever cause, may develop bleeding, either during labor or just after, when the labor itself may have been an easy one, or comparatively so.

At times the spinal canal is filled with fluid blood. The bleeding from the cord and into the skin and subcutaneous tissue may be extensive and very troublesome.

Treatment.—We will not consider the treatment of these conditions, except to accentuate the most recent teaching in this regard. Fresh human serum and whole fresh human blood (preferably the former) are the remedies, above all others, for the bleeding. They accomplish wonders, when properly used, and mark a great step forward in the therapeutic agencies employed. Many lives have been saved thereby. In cases of a hemorrhagic family tendency, antenatal treatment of the mother with calcium lactate, tonics, and possibly serum may prove of benefit.

(3) *Congenital Goiter.*—This condition, although uncommon in the United States, is one of interest and of considerable gravity. We find that, in infants as in adults, the degree of enlargement of the fetal tumor varies greatly, in different individuals. Billig in 1892 reported one of the size of a fetal head. Structurally, these tumors resemble very closely in type those seen later in life.

In intrauterine life, there are but few symptoms; at birth, the growth may impede delivery, at times even requiring craniotomy. After birth, the chief symptoms are those of pressure on the trachea, and on adjacent structures—especially the nerves.

Several cases have been reported, in which the tumor has spontaneously decreased in size, even to the point of almost complete disappearance. In other cases, the infant dies as the result of unrelieved pressure.

The interesting feature of this condition lies in the fact that it may be congenital. A considerable number of cases are on record in which goitrous mothers have given birth to infants with enlarged thyroid glands. On the other hand, there may be an absolute lack of hereditary connection between mother and offspring. Demme has reported fifty-three congenital cases, in a group of 642 adult cases.

Among the fifty-three congenital cases, there were fourteen in which both parents were suffering from goiter; twenty-three in which the mother alone was affected, and sixteen in which neither parent had the disease. Congenital goiter is found more commonly in the male sex.

(4) *Fetal Endocarditis.*—Regarding anomalies of the heart, of congenital origin, there exist two chief theories—the one theory emphasizes "structural error" as the cause of the pathological state; the other maintains that the latter condition is dependent upon fetal endocarditis.

It is likely, however, that these two views are closely related. The abnormal type may develop early in embryonal life.

Fetal endocarditis is not uncommon. The etiology, aside from its dependence upon errors in development, would seem to be similar to that of fetal diseases of the liver.

Chronic maternal infections, such as syphilis, tuberculosis, alcoholism, and certain acute infectious diseases, may readily start up inflammatory processes in the fetus, either by direct bacterial invasion or by a toxemia. At times, inflammation of either heart or liver may arise idiopathically, although this method of development naturally appears very obscure. Some such explanation, however, is necessary in those cases of endocarditis in which the mothers are free from disease.

Despite much conflicting testimony in regard to the character and form of cardiac involvement, it still remains probable that the right chambers of the heart are more readily involved during intrauterine life than the left.

Fetal endocarditis can, with care, be diagnosed before birth. John Thomson and W. B. Drummond[15] emphasize the fact observed by others, but a fact frequently overlooked, that cardiac disturbances in the fetus are all too frequently associated with other malformations. They found in a series of cases of congenital heart disease, that in three of these there were such malformations as harelip, cleft-palate, imperforate anus, malformations of external ear, and horseshoe kidney; in a fourth case there was mongolian idiocy.

(5) *Fetal Nephritis.*—Fetal nephritis is found, as a rule, only secondary to bacterial infections, or toxemias, transmitted from the parent.

It develops, not infrequently, as an accompaniment of the toxemias of pregnancy, whether with or without convulsions. In other cases it manifests itself as merely one of the sequelæ of syphilis, alcoholism, chronic lead poisoning, etc.

In addition to the rather common etiological types, there is some scientific evidence pointing to the possibility of an "idiopathic" development in certain rare cases. Even in these infants, heredity may play some rôle, although as yet obscure.

We all have seen, from time to time, cases in which albuminuria was present in the early days of postnatal life. In these instances, this phenomenon is a transient one, and may simply indicate an imperfect development of renal epithelium. On the other hand, the severe cases bear close relationship to conditions existing before birth, such as we have indicated above, or they may be the result of trauma, or of prolonged anesthesia during delivery—especially chloroform.

(6) *Diseases of the Nervous System.*—The perversions of the fetal nervous system belong essentially under the *pathology* of intrauterine life, inasmuch as they are largely dependent upon faulty development, and we do not feel therefore that they should be considered in the present discussion; we would avail ourselves, however, of the opportunity to accentuate two facts in this connection, which are of the highest importance—facts that are too often overlooked, viz.,

(*a*) While it is unquestionably true that a large number of disorders of the nervous system, such as Little's disease, ependymitis, late hydrocephalus, idiocy, epilepsy, etc., have their origin in antenatal errors dependent upon syphilis, tuberculosis, nicotine poisoning, chronic plumbism, and the like, still there yet remains a definite group of cases—and a fairly large one too—the etiology of which is dependent upon intrapartum factors. These so-called accidents of labor are (1) asphyxia; (2) cerebral compression (this may be transitory); (3) injuries to the brain or spinal cord, from fractures, hemorrhages, etc., caused by unskilful obstetrics.

The "asphyxia" may arise either from a sudden interference with the fetal circulation, or from cerebral compression, covering but a short space of time; on the other hand, it may be brought about by a gradual interference caused by a slight compression of the cord; by violent and too closely repeated uterine contractions, thus impeding the placental circulation; or by prolonged cerebral compression, due to dystocia, to dry labor, or to cerebral hemorrhages.

(*b*) Despite the fact that in most instances, the cerebral hemorrhage is of intrapartum origin, there still remain certain cases, in which bleeding (intracranial, into the pleura, and into the peritoneal cavity) is idiopathic, that is, it is found in those infants showing the hemorrhagic tendency.

The obstetrician (by either training or necessity) is without doubt responsible for many of the accidents of labor, for many fetal deaths and for much of the invalidism of those infants that survive birth; on the other hand, the ob tetrician—especially the obstetrician by training—is not infrequently blamed for results that are dependant upon factors entirely beyond his control—factors all too often dependent upon antenatal errors of development.

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Fever.—The normal temperature of the human body is the result of a constantly adjusted balance between the physiological agencies of heat production and the physical agencies of heat loss. Fever is the result of a disturbance of this balance, whereby the temperature of the body, as a whole, is raised to a variable degree above its normal diurnal range.

A symptom of many diseases, fever has distinct pathological expressions of its own. Significance no longer attaches to terms descriptive of the qualities of fever; stress is no longer laid upon its distinctive types. It is one and the same thing in process. Its causative factors, if individually specific, have a definite group relation. Its term varies with the character of the infective organism. If it exhibits any individualism, it is that of the subject of attack. Sthenic and asthenic forms are, the one, the fever of the nutritionally strong; the other, the fever of the nutritionally weak. Marasmic tissues are poor soil for the development of fever.

THE CAUSES OF FEVER.—It is not to be supposed that all disturbances of the normal balance of heat production and heat loss constitute fever. Many and constant are the influences which tend to raise or to lower the level of body temperature by creating differences either in heat production or in heat distribution, but, ordinarily, these are met by compensatory regulation. The occurrence of fever predicates a sensitized mechanism responsive to an unusual stimulus. So definite is the reactive formula of fever as to suggest the tempting hypothesis of an identical sensitizer. So uniform is its process as to raise the issue, if not of a single cause, at least of similarly operating causes. Many and difficult as are the problems which this hypothesis presents, indications are not wanting that apparently remote causes of temperature disturbance have proximate relations.

The term "pyrogenic substances" is a generalism; for, as Schittenhelm says, in criticism of the specific fever-toxin theory of Friedberger, the facts speak for a multitude of toxic fever-producing agents. Nevertheless, the history of their varied pyrogenic influence tends to focalize attention upon certain common

likenesses of relation and a certain uniformity of process. The facts which bear upon this common relationship and this identity of process may be briefly stated.

(1) Of the many substances, entering or formed within the animal body, which exercise a pyrotoxic power, all belong to the protein groups and all of them, no matter how variant in composition, develop a true proteotoxicosis.

(2) This general fact establishes a group relation for all forms of fever. That relation may be traced:

a. In experimental fevers, of the anaphylactic type, to the introduction of foreign proteins, which, in their breakdown, form toxic derivatives.

b. In experimental fevers, of the aseptic type, caused by the introduction of chemicals, colloidal metals, paraffin, etc., to alterations of the colloidal equilibrium of the blood and the tissues and to a consequent splitting of cell proteins and a liberation of toxic products.

c. In traumatic fevers, as in extensive fractures or operative wounds, or in contusions involving interstitial hemorrhage and blood clot, to the destruction of cell proteins, in the course of the disintegration of which toxic by-products are separated. A peculiar readiness of dissolution is manifested by certain cells and notably by the blood platelets. In certain subjects, a ready tendency to destruction of cell proteins is an index to the easy excitation of fever.

d. In neurotic fevers, associated with profound disturbances of protein metabolism, to the evolution of imperfect nitrogenous metabolites, by-products of which are toxicosic in character. Such disturbances of body temperature are frequently seen in severe functional neuroses and are occasionally profound in hysteroepileptics.

e. In fevers of autotoxemic origin, to the absorption of protein putrefacts from the intestinal tract, in consequence of a breaking down of the epithelial barrier of the bowel resulting from certain forms of bacterial activity, usually of the saccharo-butyric type.

f. In fevers of bacterial origin, to the destruction of cell proteins and the counterdestruction of bacterial proteins within the invaded body; the proteotoxic products of bacterial origin having greater toxicity, as all foreign proteins have, than those of native source.

g. In fevers of parasitic origin, particularly of the spore-producing types, to similar destruction of cell proteins and especially of blood elements, and, in turn, of parasitic proteins.

(3) These protein pyrogenic substances of variable origin and varying toxicity are always intermediate products of protein breakdown of relatively high molecular quality. They belong to a class of protein split-products which fall short of resolution into the ultimate and innocuous building-stones of protein metabolism which normal enteral digestion secures.

It is unnecessary, and might prove unprofitable, for the purpose of this review, to discuss the involved and debated questions as to whether these protein toxigens are formed within the body as the by-products of a parenteral digestion, or as to whether they are produced by enzymes previously present, responsively produced, or merely activated for the occasion in the blood or the tissues. In spite of much valuable work, recently done on these problems, it is still impossible to say whether the specific *infekt* directly excites the centers of heat production, or whether, with the consequent development of antibodies, the withdrawal from the blood of a binding complement is directly responsible for this thermostimulative influence. The weight of evidence is against the single entity of the toxic agent; it is, indeed, rather in support of its specificity in each and every type of infection; while the work of Citron, Leschke, and others tends to dip the scales of argument toward a quantitative relation of the binding complement to the fever-producing mechanism. The one hypothesis proposes an identical sensitizer of the heat regulating machine; the other speaks for an identical sensibilizing process. The latter theory accounts satisfactorily for the variable quantitative element in fever in either one of two ways. A slight infection may call for few antibodies and for the minor consumption, therefore, of complement; it will beget but a slight disturbance of body temperature. In the efficient subject of invasion, a pronounced infection will reverse this result; while in the nutritively inefficient, the inability to form antibodies puts small demand upon the constant complement and fever response is slight. The subject belongs to a common class of poor fever producers.

This hypothesis, again, tends to establish the essential unity of the fever process. It suggests an analogy between the incubation of infective fever and the temperature development in anaphylaxis; the one being as much a sensibilizing event as the other. It accounts, too, for the fact that organisms, previously infected with a given toxin, react more definitely than they do when they present a virgin soil to such an *infekt*. Smaller doses are required to produce pyrotoxic results. Repetitional doses become intensive. The readiness of sensibilization is in direct ratio to the rapidity of protein breakdown. Schittenhelm admits that while the bacterial toxins are specific and produce specific immune bodies, the phenomena of sensibilization to fever may be common to all invasions. Fever, says Leschke, is always an immunobiologic reaction.

This theory of a common sensibilizing process goes far to explain the variations in the several types of fever, the temperature curves in primary and secondary infections, and the methods of fever termination whether by crisis or by lysis. A sudden decline of temperature may depend, occasionally, upon the exhaustion of heat-producing centers; but the ordinary course of fever subsidence, whether by remission, by sudden defervescence, or by gradual and permanent fall, marks the detoxication of the blood and its recovery of free complement. Ludke has shown that during a period of from twenty-four to thirty-six hours prior to pneumonic crisis, the blood is poor in precipitins and in complement; but that during and after crisis, these are enormously increased. By treating infected animals with pneumotoxic sera derived from pneumonic individuals in crisis, he greatly multiplied these protective agents in the blood and effected rapid and complete recoveries. Hektoen corroborates these findings, proving that in pneumonia crisis there is a rapid concentration of protective bodies and an equally rapid destruction of bacteria in the blood.

Similarly, Citron and Leschke relate the development of anaphylactic fever to the withdrawal of blood complement by fixation. They suggest, too, that in aseptic fever, whether produced by the introduction of chemicals, colloidal metals, or autolytic substances, the rise of temperature is directly resultant upon a like withdrawal or binding of complement. Much work remains to be done not only toward a better recognition of the several intermediary products of protein breakdown, but toward a better understanding, also, of their biologic and physical behavior in the living animal organism.

THE TYPES OF FEVER.—It is the purpose of this review to discuss fever, rather than fevers in severalty, but in so far as individual forms exhibit types of temperature disturbance it is desirable to determine, so far as possible, the principles which govern their classification. Only those fevers which are of clinical interest and invasive origin can be included in this consideration. These may be grouped as:

a. The culminative fevers, tending to crisis, as in pneumonia.

b. The terminative fevers, of brief and self-limited duration, associated with a phase of efflorescence, as in scarlet fever, measles, smallpox, etc.

c. The continued fevers, as typhoid fever, sepsis, and tuberculous fever.

d. The cyclical or intermittent forms, as in the malariæ.

e. The remittent or recurrent fevers, which equally with the intermittent types, are of parasitic origin, but of doubtfully malarial quality.

Such an attempt at classification suggests, at once, that in each group, a biologic equation obtains, in which one and the principal factor is the life history of the invading organism; and the other, a responsive factor, is the combative capacity of the infected subject expressed in terms of the physiological weapons which his nutritive status permits him to muster.

In the culminative fevers, the battle with the bacterial toxins is brief and overwhelming, or ends in a mass gathering, as it were, of bactericidal forces by which the acute toxicosis is overcome.

In the terminative fevers, the conflict is less sharply defined in point of time. A successful issue usually depends upon the absence of mixed or superimposed infections, which take advantage of lowered immunity and convert the fever into a continued type.

The continued fevers present the picture of a long-sustained siege, in which a daily struggle between protein toxins, alike of bacterial and cellular origin, and specific antibodies is maintained to an indeterminate conclusion; and in which secondary and frequently septic infections may serve as reinforcements of the primary invaders.

In the cyclical or intermittent forms of fever, unaltered by therapeutic measures, the equation is very largely a uni-factored one and the part which the forces of physiological resistance play is very uncertain. Fever periods are determined by the successive sporulations of the plasmodia and their continued recurrence is dependent rather upon the length or endurance of the stage of schizogony in the polymorphic history of these invading parasites, than upon any determinable limits set by the development of immunic conditions in the invaded. Doubtless the paroxysms of fever produced by the liberation of sporular toxins have a direct effect upon the rapidity with which this irruptive stage is fulfilled. The fever reaction is, in so far, protective while it lasts, but, apparently, is not preventive of the evolution of new cycles.

In the remittent fevers, the balance of the biologic equation is continually reversed. Periods of abatement are distinctly characterized by the concentration of antibodies and the increase of complement in the circulating blood. As these protective agents are again exhausted, the opportunity of reinvasion occurs. It is a running fight, with alternating advantage between invaders and invaded. Mixed infections, as Sir Patrick Manson has shown, are sometimes responsible for the idiosyncrasies of these forms of fever.

Many obscure cases of temperature disturbance may be noted, especially in childhood, which are traceable either to the occurrence of localized infections, or to an easy excitation, through some slight general toxicosis, of the mechanism of temperature regulation in early life.

The Seats of Fever.—A major part of the fruitful work that has been done, in recent years, upon the problems of animal heat, has been devoted to the study of the central heat-regulating mechanism. But little attention has been paid to the thermogenic and, presumably, fever-producing tissues. So far, however, as inquiry has gone, the physiologist cannot get away from the conclusion that the production of heat is a function of the cell at large; that fever, howsoever originating, howsoever controlled, is a disturbance of intracellular metabolism. The evidences of the fact are many.

We recognize local reactions to invading organisms or their toxins; but we do not sufficiently appreciate the truth that these reactions are in the nature of miniature peripheral fevers. Let the infection extend beyond its initial focus, and a general rise of temperature results.

In seeking for the seats of fever, we should note that the homoiothermous animal is not one of fixed or constant temperature, but simply one of regulated temperature; that, indeed, the heat conditions in one part of the body differ markedly from those in another part; that, within normal range, the temperature of the skin, of the blood, of the muscular tissues, of the great glands, and of the central nervous system vary on a scale of at least five degrees, Fahrenheit. This, in itself, carries sufficient proof that the several tissues are contributory to the sum of heat production and, therefore, of fever, in very varying degree.

The contribution which each makes is dependent upon three things: (1) the bulk of tissue, (2) the continuity of its energy output or functional employment, and (3) the rapidity of its metabolism within a given time. To the first two of these considerations, the muscular tissue responds, in a major degree, as a principal source of heat. Its great mass, the number of its physiological units and the constancy of their employ, all point to its large heat-forming function. The comparatively slow rate of its metabolism does not greatly discount its predominant share. Direct observation shows that in the contracting muscle, exercised within the limits of exhaustion, the temperature rises 1.5° F.

The glandular tissues come in as a second, although a distant one, to the muscular system, on the score, alike, of their large bulk and their great rapidity of metabolism. The blood which enters the liver at an average temperature of 99.8° F., leaves it, during active digestion and absorption, at a point which varies between 103.8° and 105.2° F.

As an active heat-producer, despite its relatively small mass and on account of both continuity of employment and rate of metabolism, the nerve tissue in general, and particularly the central nervous system, takes third place. Beside these three chief contributors, other tissues play a minor part. It is upon these major seats of heat production that the thermogenic burden mainly rests.

Hans Meyer goes so far as to suggest an intrinsic organal regulation of temperature—an automaticity of local thermogenesis. A broader view suggests the existence of autonomic centers of local influence, but under a general thermotaxic control. That local temperatures may be maintained after section of the spinal cord at the lower cervical or first dorsal segments is significant.

Certain organs of internal secretion influence the thermogenic function of the tissue cells at large. In the hyperthyroidea, the level of excitability to thermogenic influences is raised. The subject lives at a higher heat potential. Reversely, in the hypothyroidea and in disease of the anterior hypophysis, the threshold of temperature responses is lowered. Cushing points out that in such cases it is difficult to induce fevers, and suggests that a depression of thyroideal or hypophyseal function induces hibernation. Proof of this thermogenic depression is established by a reversive action under thyroid extract feeding. That these metabolic influences affect, also, the central mechanism of heat production will be observed later.

The phenomena of sensibilization suggest not alone a centric, but a peripheral influence in thermogenic reactions. That organisms previously infected with certain toxins react more speedily and more profoundly than they do in a virgin state is a function of sensibilization which means their progressive acquirement of biological weapons for the swift destruction of foreign and toxic proteins.

The feeble temperature reaction of exhausted tissues is negative proof of peripheral thermogenesis in the

normal subject. The action of therapeutic agents which insensitize the tissues to thermogenic response is corroborative.

The Metabolism of Fever.—It is difficult to draw a desirably sharp distinction between the pathologic accompaniments and the pathologic consequences of fever.

If fever is the end result of a proteotoxicosis, or rather of a physiologic process by which that toxicosis is met, it is not the only effect of the primary cause. The immunic reaction to the toxicosis is in the nature of a metabolic disturbance more or less profound. The fever is an essential part of that process. At the same time, the toxicosis occasions, in itself, metabolic changes, not only of a specific, but of a very general character. As the recent work of Rahel Hirsch suggests, these temperature and metabolic disturbances are not always concurrent, nor do they always run on parallel lines. It should be understood that the term metabolic is distinctively addressed to those serial changes in the tissue cells by which energy is evolved, through the expenditure of whatsoever form of material, as well as to those structural changes in which the cell proteins are attacked. Emphasis should be laid upon the fact that physiologic or pathologic, in kind or in degree, these metabolic events, whether energy-evolving or structure-changing, occur within the tissue cell. Whether they involve the serial oxidation of fats and carbohydrates alone, or extend to the cleavage and oxidation of protein material, these reductions are brought about through the agency and influence of cell products. It is not necessary to discuss the doubtful question as to whether these ready energy-producing food stuffs become an actual, if unstable, part of the tissue cell, or whether they represent simply the fuel store, or floating capital, of the cell. It is enough that their consumption occurs within the cell and involves, in its accomplishment, the metabolic activity of the cell. This, in itself, makes it futile to draw any sharp line between the metabolisms of nitrogenous and non-nitrogenous material. Moreover, in fever toxicosis, as in starvation, let the body store of the non-nitrogenous stuffs fail and the protein fund will be at once invaded. In ordinary hunger, the body draws upon its non-nitrogenous supplies and maintains a minimal output of nitrogens. In fever, it does the same thing up to the limit of these available stores and, as May and Staehelin have shown, so long the protein metabolism is not increased. Let these simpler energy-producing materials be exhausted and a compulsory breakdown of cell-proteins ensues. While it may be insisted that metabolic and temperature disturbances are the twin results of a proteotoxicosis, it must not be forgotten that once created they form the hemi-arcs of a vicious circle. For under increased temperature, in vivo as in vitro, chemical reactions are accelerated and fever becomes the promoter of an increased destructive metabolism. As van't Hoff has shown, with a lift of ten degrees in temperature, chemical reactions are doubled or trebled in velocity, giving a temperature coefficient of between two and three. On the other hand, physical processes under the same degree of heat, show less than half the increased velocity; they have a temperature coefficient of between one and two. It will be seen that in fever the wheel of relationship between metabolism and temperature again turns. The increased body temperature induces more rapid metabolic reactions, chemical in character and resultant in higher heat production; while less favorably it affects the physical agencies of heat loss. The sum of result is greater heat storage. It may easily be imagined that this intrinsic heat accumulation is one of the essential features of the immunobiologic reaction by which the proteotoxicosis is met.

The most significant accompaniment of fever is seen in the glycogenic field. The increased output of sugar in the subject of fever has been demonstrated by Liefmann, Stern, Hollinger, Silberstein, and others. That the temperature disturbance and the carbohydrate release are in the nature of a physiologic equation is indicated by the normal rise in the blood content of sugar, under the stimulus of continued cold weather and its corresponding fall in warmer seasons. Fever is always accompanied by or associated with hyperglycemia, which, in itself, merely signalizes the mobilization of sugar for heat-producing purposes in the tissue cells. That this is an associative phenomenon of heat regulation, is shown by the fact that severance of the spinal cord at the first dorsal segment cuts at once the twin paths of influence for glycogenic activity and heat production. By section below this point, these cooperative functions are not suppressed. Their functional relationship is suggestive of the dietetic treatment of fevers.

Certain accompaniments of fever are apparently results of the conjoined influence of the primary toxicosis and its induced rise of temperature. Among these, are the acceleration of heart action, the variations of blood pressure, the excitation of a polypneic center and of the nervous mechanism governing the sweat glands. The discussion of the relationship of these factors in fever will be enlarged in the study of the mechanism of its control.

That fever is a self-limited function is both directly and indirectly true; since it appears that high body temperature is destructive to many pathogenic and fever-producing organisms.

The Mechanism of Fever.—The best argument for a homoiothermic mechanism is the absence of it in the poikilothermous type. Constancy, without uniformity, of temperature; local variations of heat, adjusted by compensatory influences in the body at large; the continual equalization of differences in heat production and heat loss, presuppose a regulative mechanism which puts in striking contrast the temperature-tossed conditions of the "cold-blooded." The higher, in fact, the type of living organism, the more numerous are the causes of temperature disturbance to which it is liable and the greater the need of thermostatic control. The diurnal range which the body temperature exhibits, susceptible as it is of numerous minor variations, responsive as it is to major stimuli of change, indicates the pendular swing of a function which traveling, on occasion, within a lesser or a larger arc, tends constantly to the adjustment of its own excursions from a permanent center.

The operative features of this temperature mechanism suggest, at one and the same time, its centricity and its autonomy. Localization, distributive relations, and function alike indicate its wide control both in the somatic and the visceral fields. Certain observations show that distribution of impulses is largely had through the paths of the sympathetics. The influence of such drugs as cocaine and adrenalin upon temperature tends to support this view.

Experimentally, by destruction of both corpora striata and optic thalami, or by enucleation of the stellate ganglion, or by division of the roots of the lower cervical nerves, or by section of the cord at the first dorsal segment, or by the action of curari upon nerve terminals, the conversion of the homoiothermous into a poikilothermous animal has been clearly proved. It is of especial interest, for the purposes of this discussion, to note that in animals so treated, pyrogenic substances, so-called, are without temperature effect. Moreover, in animals whose temperature mechanism has been previously excited and who have then been submitted to similar experiments, the pyrexia has been found to sink.

In the intact subject the heat-regulating mechanism may be reached by thermal, mechanical, chemical, or electrical stimuli. It is clear that the stimuli ordi-

narily active upon it are those of extrinsic cold and heat. As a final proof of the existence of these regulative centers may be noted their exhaustion by overstimulation and the lack of compensation frequently observed when excessively high or extremely low temperatures are encountered.

Despite the cumulative evidence in favor of centric control, the possible automaticity of temperature conditions in certain tissue cells is not to be overlooked. It appears, however, that such automaticity is always in the direction of the poikilothermal response. Cold diminishes and heat accelerates the chemical reactions upon which the evolution of heat within the cell depends. Still, it is not impossible that the normal protein metabolism may furnish products which regulate, in a degree, the ordinary energy output of the cell.

The recent researches of Barbour and Wing not only corroborate the investigations of others in localizing the centric seats of temperature regulation, but they prove the direct influence of stimuli upon this central mechanism. The phenomena of heat puncture have been repeatedly observed and have been attributed to an excitation of thermogenic centers. Barbour has directly proved that this is true, by experiments in which puncture is effected by means of canulæ, through which repetitional and varied stimulation has been had. Upon the subsidence of the initial excitatory effect of the puncture, Barbour has applied, by this ingenious method, electrical, thermal, and therapeutic stimuli with remarkably consistent results. He confirms the like observations of Krehl and Isenschmid in the field of electrical stimulation. To the conclusions drawn from these researches, later reference will be had. They serve to show the immediately responsive power of the central heat mechanism.

No exact limitations can be set, at the present time, to the localization of these heat centers, but their existence and approximate situation appear to have gone beyond denial and certain facts of their relationship have been well worked out. Undoubtedly, their associative and distributive tracts are numerous and widespread, and this introduces, at once, large difficulties into the interpretation of stimulative phenomena and into the definition of a precise locus of the actual nuclei of control. That there are secondary centers concerned in the distribution of thermogenic impulses seems clear. That the mechanism is a bilateral one is assured. That the thermotaxic centers are multiplex and exercise thermogenic and thermoinhibitory functions appears probable. It is possible to secure, by central stimulation, either the increase or the reduction of body heat. Reduction may be accomplished by a diminution of thermogenic action or by thermoinhibition. The relation of the mechanism of thermotaxis to that of thermolysis is very close. The forces of increased heat production and peripheral vasoconstriction normally cooperate, although in fever, they are frequently dissociated. The agencies of heat inhibition, of peripheral vasodilation, and of increased respiration and perspiration commonly act in harmony. Physiologically, these several mechanisms are continually excited by appropriate stimuli; they respond readily, now cooperatively, now antagonistically, and with the result of a rapid adjustment which forestalls discernible changes of temperature in the body at large.

A broad localization of thermotaxic centers, extending from the forepart of the corpora striata through the optic thalami and including the hypothalamus, may be made. The indefiniteness of the statement is recognized, but it gathers within it the range of seemingly successful experiment. In the present state of our knowledge, it is well to establish only the wide limits of actual definition. Section in front of the anterior quadrigemini produces poikilothermia. Leschke states that such section must involve in this isolation the hypothalamus in order to produce this result, and he locates the heat centers, broadly, in the basal ganglia of the fore- and interbrain. Barbour, while forbidding too close anatomical limitations, secures his optimum results in the stimulation of the caudate nucleus of the corpus striatum. Nicolaides and Dontas obtained maximal rises of temperature by puncture through the midportion of the caudate nucleus, involving, also, the tuber cinereum. Good hyperthermia could be had, however, without the implication of the tuber. They procured less-marked results at the anterior extremity of the caudatus. Puncture of the posterior portion of the caudate nucleus indicated thermo-inhibition.

Trypanosomic and bacterial infections have failed of pyrogenic results when experimental isolation of the thermotaxic mechanism; as outlined above, has been had. Anaphylatoxic reactions have similarly failed under these conditions.

No evidence has yet been secured to suggest independent centers for the government of heat loss. In fever, as under normal heat conditions, thermolysis is controlled through respiratory and sweat centers and through the vasomotor field.

The thermotaxic mechanism exhibits the phenomena, markedly characteristic of all autonomic centers, of tendency to easy increase and diminution of irritability, to widening of the range of functional expression, and to ready exhaustion. In early life, these qualities are emphasized by the particularly wide swing of the pendulum of temperature variation. In old age, changes of irritability are easily excited, within a narrower range of excursion, but with great liability to thermotaxic exhaustion.

Physiological influences undoubtedly serve to vary the susceptibility of the heat centers to temperature stimuli. The hyperthyroidea suggest a normal relationship of the thyroid body or its accessories to the preservation of heat balance, in the fact that they definitely raise the level of responsive power in the thermogenic mechanism and even appear to lower the threshold of reaction to a given stimulus. Reversely, the hypothyroidea, together with disorders of the hypophysis, reduce the range of excitability and lift the threshold of reaction to the minimal stimulation of heat production.

Certain drugs induce very similar results. The phenomena of sensibilization under anaphylaxis also suggest, as one phase of the process, a sensitizing of the heat-producing centers.

The phenomena of fever establish like relations. The incubation period of any proteotoxicosis creates conditions which sensitize thermogenic centers and apparently inhibit or depress the centers which determine the cooling of the body. The thresholds of response are lowered and their limits of temperature control are raised. Consequently, a normal temperature acts in fever as a cold one does under physiologic range; while a high heat is necessary to limit thermogenesis or to excite thermoinhibition.

The fevered organism regulates its own temperature disturbances, after the same fashion, but within wider range, as the normal body does. As the heat-producing and heat inhibiting centers are ordinarily sensitized by seasonal changes of temperature, so they become sensitive to fever. The physiologic rhythm of heat regulation is broken, but a new one is set to meet the unusual thermogenic pace. The height of heat production and the level of thermostatic control are in direct ratio. The balance between heat production and heat loss is disturbed, but it still makes exaggerated efforts at adjustment.

The physiological method of fever control follows normal lines. Like other autonomic centers, those of heat regulation are susceptible not only of reflex, but of direct stimulation. The fevered blood is its own depressor or inhibitor of thermogenesis, through

its immediate action upon the heat centers. Barbour's work has gone far to establish this interesting conclusion. By the introduction of hot water through his puncture cannula he proved the effect of highly fevered blood. The heat acted as a stimulus to thermoinhibition, or as the calmative of thermogenic centers, and the body temperature fell. So, external heat or hyperpyrexia ultimately sensitizes the subject to control and heat production is checked or counterbalanced. Similarly, introducing cold water, he reversed the regulative process. A direct stimulus to thermogenesis was provided and the body temperature rose. So, external cold or a subnormal body temperature sensitizes the subject to thermogenic stimulation.

It must not be forgotten that a physiological corollary of overexcitation is exhaustion. Sudden and extreme fever reactions do not always spell control. Rather are they occasions for concern. They indicate the loss of thermogenic power. The paralysis of heat-producing centers by continued stimulation with excessive cold is in point. Extremes of counterstimulation meet. Recovery of control is often a slow process.

The cooperative influence of thermolytic agencies in the adjustment of temperature conditions in the fevered subject must not be overlooked. Compensation is only second in importance to thermotaxis in the control of body temperatures, whether in health or in disease. Emphasis has been put, already, upon the close relation between thermotaxic and thermolytic centers and reference may again be made to the experiments of Barbour and Wing in this field. They have shown that direct heat stimulation of heat-regulating centers not only diminishes heat production, but excites vasodilatation, thus increasing the opportunity of heat loss. Similarly, direct stimulation by cold not only excited thermogenesis, but induced marked vasoconstriction, thus conserving body heat.

In the human subject, the skin plays an important part in the regulation of temperature. Three agencies are operative to this result, radiation and conduction of heat and evaporation of the water of perspiration. All of these are influenced by vasomotor action in the cutaneous areas. The sweat glands, however, come under specific control. Their centers do not appear to respond directly to temperature changes in the blood, but are rather influenced by chemical conditions incident to the fever toxicosis. It is usually in the stage of crisis or in the somewhat rapid lyses that mark the course or follow the decline of continued fevers that they show any marked degree of stimulation.

Coincident with, or consequent upon, the higher ranges of fever, another active agency of heat dissipation is developed. The thermotaxic centers of the corpora striata, at a certain level of stimulation, exhibit a relation to the respiratory centers whereby the phenomenon of heat polypnea is excited. That this is an associational event is proved by the fact that section anterior to the quadrigemini cuts the path by which polypnea is induced.

The Treatment of Fever.—The modern conception of fever is of a physiologic process by which disease toxicoses are met and the defenses of the animal body are reinforced. It is a conservative force, set in action by a self-regulating heat-producing mechanism; capable, within functional limits, of the control of its own hyperactivity, so soon as the causes of excitation are neutralized or removed. Its suppression is a therapeutic mistake; its violent reduction a clinical blunder. Its extremes only are to be carefully modified; its nutritional inroads repaired; its exhaustive consequences averted.

The occasion for combat is not with the fever, but with its causative agent should it lie within possible reach of therapeutic weapons. It is not desirable to check those chemical or biologic reactions upon which the evolution of defensive agents depends. An organotropic remedy reaches only to effects. Etiotropic remedies, capable of the destruction or the discouragement of invading organisms are alone worth the seeking and, unfortunately, they are rare. Quinine in malaria, salvarsan in remittent fever, and atoxyl in trypanosomiasis are true antipyretics of a very slender group.

The ordinary antipyretics are merely narcotizers of thermogenic centers—centers which serve as the ammunition train in the biologic battle. They put those centers, untimely, out of commission. In fact, the conservative quality of hyperexia is shown in the protection it affords by its own control. An excessive temperature tends to narcotize the entire brain of its subject and, with it, the temporarily overactive thermogenic centers. Those centers do not need to be battered into insensibility; they put themselves to sleep, on occasion, by the influence of their own pyretic product. Drugs of the antipyretic class have proved essentially mischievous in careless therapeutic hands and increasingly useless to the trained clinician.

If narcotization is desirable in fever cases, it is not to control thermogenic centers, but to diminish the general excitability of the nervous system. In this event, careful selection of drugs should be made, to the exclusion of the ordinary antipyretics. It should be remembered that alcohol, chloroform, ether, chloral, and morphine have no selective action for thermogenic centers, but paralyze thermoinhibitory centers as well. Krehl calls attention to pyramidon, a minor antipyretic, but an agent which quiets and clears the sensorium and improves respiratory action.

In marked hyperpyrexia, accompanied by high blood pressure, it may be well to seek the stimulation of the thermoinhibitory or cooling mechanism. The drugs which have a selective action upon these autonomic centers include aconitin, digitalin, veratrin, and picrotoxin.

In the sudden low temperature reactions which occur in the course of crises or of prolonged continued fevers, caffeine fills a rather distinctive rôle as a reexcitor of heat production. It is difficult to select drugs which have a characteristic effect upon thermolysis, which do not, at the same time, influence heat production.

There has been a very general revision of hydrotherapy as applied to fevers. At the present day, it is not so much employed, in any of its methods, for the reduction of temperature, as for its sedative influence over nervous irritability; its stimulative effect, in certain forms, upon vasomotor tone; its eliminative encouragement of the skin; and its contribution to the general comfort of the fevered patient.

The epitaph of Dr. Graves, "He fed fevers," will be appropriately engraved upon the tombstones of many modern clinicians. Like many another revival, the feeding of fevers has been carried to an indiscriminative excess. Even in the practice of scientific medicine, men become enamored of an idea and push it to illogical conclusions. Nevertheless, fever feeding is a problem for careful study.

Fever is a battle in which the nutritive forces of the body are definitely engaged. The problem of its dietary should be—Required: to maintain a daily nutritive balance, within the limits of the fevered subject's digestive power. Several factors are to be taken into account. The prior nutritive integrity of the patient is a large one. Given an adequate store of glycogen and of fat in his tissues, it represents a directly available supply of thermogenic material which can be mobilized at small expense of energy. That it will be mobilized, concurrently with the course of the fever, is a matter of demonstration. In many such cases, the low ebb of functional activity in the bulk

tissues of the body being remembered, but a modicum of food will be necessary to recoup the losses in this mobilized material. In the inadequately nourished body, it may be necessary to provide a far more liberal supply.

The height and probable course of a given fever are matters for consideration, as indices to the utilization of thermogenic material. The successful elimination of the products of combustion, in any given form of disease, is to be reckoned with. The possible diminution of oxygen supply is to be noted. The age and the weight of the subject are to be figured into the account.

The choice of food material and the form for its easiest ingestion should be studied. Forced feeding is rarely successful feeding. Fats are commonly more objectionable to the fevered patient than are the carbohydrates. The liability of the sugars to fermentation, at high body temperatures, throws the major burden upon the starches, which should be reduced to a thoroughly soluble form. Maltose, by preference, among the sugars, may be added to these and its usually contained diastase assists the digestion of the starches. A combination of these materials with milk, in the form of gruels, will be of readiest administration and digestion. The fact of fever thirst renders liquid food the more acceptable. And appetite, as an aid to digestion, is not to be ignored, even in fever. Flavors can be sufficiently varied in such preparations.

The total nitrogen output constitutes, after all, a safe index to the adequacy of food supply in fever. Protein metabolism is not, of necessity, increased. If it is, it may be taken as proof of demand for freer feeding. The purin bases aside, it is ordinarily true that protein destruction only follows, in fever, upon proximate starvation of more available thermogenic material. Protein foods may always be minimized, and with profit.

The generous water supply of the subject of fever is quite as important as his sufficient feeding. His water consumption is commonly great. The flushing of actively thermogenic tissues; the dilution of toxin-laden blood, the active elimination of waste products are alike favored by a full water diet. Water is, at one and the same time, a valuable form of food and an indispensable medium of interchange in the currency of fever. RICHARD OLDING BEARD.

Fibrillation, Auricular.—See *Arrhythmia, Cardiac.*

Fibrillation, Ventricular.—It has been demonstrated experimentally on some of the lower animals by the conjoint use of the myograph and electrocardiograph, that fibrillation may be ventricular as well as auricular. This has been done by Lewis, who (1) tied the descending branch of the left coronary artery in the dog, and also (2) obstructed the blood flow in the right coronary. In this way he was able to induce premature ventricular contractions, which succeeded one another at shorter and shorter intervals, at first singly and then in groups. This irregularity led to great frequency of the pulse, the rate rising to 300 or even 420. Eventually there was delirium cordis. Lewis was also able to induce ventricular fibrillation by (3) irritating a large papillary muscle, (4) the central surface of the right ventricle, or (5) its lower angle. Under these excitations the normal pulse rate was overcome by the extraneous, the so-called heterogenetic, or ectopic, impulses. Ordinarily on suspending the irritation or relieving the obstruction the normal pulse rate was restored. Incidentally it was found that neither irritation of the pneumogastric nor section of it caused ventricular fibrillation.

Further experiments by Lewis in coöperation with Levy showed that ventricular fibrillation could be induced in cats by chloroform anesthesia. Heart failure followed. Also in the same animals intravenous injections of adrenalin chloride, in doses of from one-quarter to one minim of a 1:1,000 solution, under light anesthesia, produced similar results. There was seldom complete recovery in these latter cases. On the other hand, the administration of the adrenalin solution under *full* chloroform anesthesia was not followed by these dangerous results.

Hoffmann in a patient with paroxysmal tachycardia, was able to demonstrate ventricular fibrillation by the electrocardiograph. The patient recovered. From the above citations it is evident that our knowledge of this subject is as yet fragmentary, but it is well to bear in mind that there is danger in the intravenous injection of adrenalin chloride under light chloroform anesthesia, and that any injury to the substance of the ventricle or any obstruction to the coronary circulation may cause this form of fibrillation.

THOMAS E. SATTERTHWAITE.

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Fibrin is an insoluble protein belonging to the group designated as derived proteins. When blood is drawn a clot is formed and fibrinogen a soluble protein is transformed into fibrin. Fibrin is the basis of the clot. See *Blood.* F. P. U.

Fibrinogen occurs in blood as one of the principal constituents of the plasma. It is a protein belonging to the globulin group and under the influence of a ferment is transformed into fibrin when blood clots. Fibrinogen is also present in lymph. See *Blood.*

F. P. U.

Fibrolysin.—See *Thiosinamine.*

Fibroma.—A fibroma is an autonomous new-growth composed for the most part of the cellular and intercellular elements of fibrous connective tissue. It is commonly accepted as the type form of benign mesoblastic tumors and has its physiological prototype in mature connective tissue. Since the fibroma is a true neoplasm; all of the various types of connective-tissue proliferation which are dependent upon chronic inflammatory processes must be excluded in the use of this term.

Fibromas may be divided into the *simple* forms, which are composed wholly of neoplastic fibrous connective tissue and its accompanying blood-vessels; and *mixed* forms, in which there is a combination with one or more other types of new-growths. The mixed fibromas are by far the more numerous. Under each of these two main headings there may be described various subvarieties, the recognition of which depends upon differences in consistency in some cases and in others upon differences in general morphology or location. So varied are the bases for these differentiations that it is impossible to group all of them under logically correlated subdivisions.

SIMPLE FIBROMA.—The simple fibromas are divided according to consistency into two groups. The denser sort is spoken of as the *hard fibroma*, or *fibroma durum*, and the less dense as the *soft fibroma*, or *fibroma molle*. Between these two all gradations of firmness are to be found and oftentimes hard and soft areas are present in the same growth. Either type may occur wherever connective tissue is found, but in a general way it may be said that the fibroma durum usually arises from dense connective tissue such as tendon, and the fibroma molle from more areolar

connective tissue such as that of the subcutaneous layer.

Fibroma Durum.—The hard fibroma occurs as a rounded or nodular tumor which is usually sharply circumscribed and encapsulated, of a pinkish-white or pearly white color, and which presses surrounding structures aside in its expansive growth. Although sometimes rather diffuse instead of being encapsulated, the fibroma is never infiltrative. Upon sectioning such a tumor it is found to be very dense and firm, often creaking beneath the knife as it is being cut. When very hard and tough such a fibroma is frequently spoken of as a *desmoid*. The cut surface shows a compact fibrous structure with the fibers arranged in parallel bundles and whorls. Microscopically these bundles are seen to be made up of masses of fibrils among which connective-tissue cells are scattered in varying numbers, the more dense and more slowly growing the tumor, the fewer are the cellular elements. The nuclei are oval or spindle-shaped and arranged for the greater part with their long axes parallel to each other and to the fibrils among which they lie.

Knowledge of the finer histology of fibromas has been much advanced by the work of Mallory, who has found in these tumors the same fibrillar structures as can be demonstrated in the intercellular substance of normal connective tissue. According to Mallory

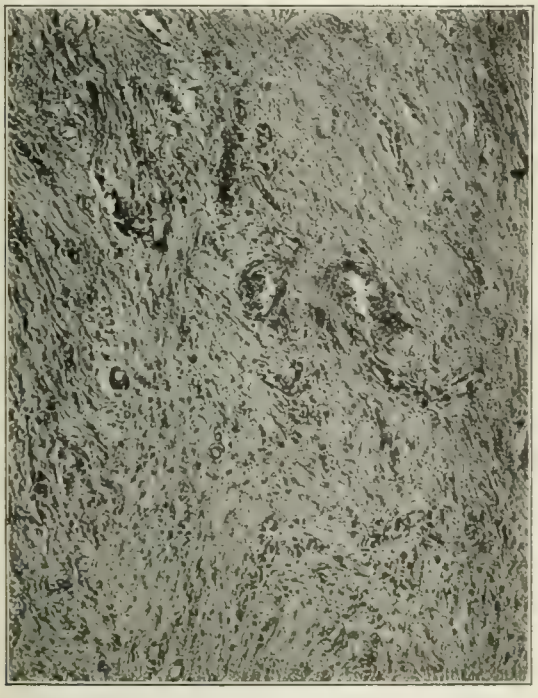

Fig. 2390.—A Fibroma Durum of Subcutaneous Origin. Stained with hemalum and eosin. Zeiss obj. "B."

two kinds of fibrils are to be recognized by their morphology and differences in staining properties. These are *fibroglia* fibrils which run along the surface of the cytoplasm in the direction of the long axis of the cell, are straight or gently curved in their course, and pass on apparently from one cell to the next; and *collagen* fibrils which lie alongside of the cell but not attached to it and are fine and wavy in appearance.

There are wide variations in the degree of vascularity which these tumors may exhibit. Some show relatively few vessels coursing through the central portion of the whorls of fiber bundles, while at the other extreme are the growths so richly supplied with dilated blood-vessels that they are often described under the heading of *fibroma telangiectaticum*. As previously mentioned, the hard fibroma may be found wherever connective tissue occurs, but the sites of predilection are the subcutaneous, the intermuscular, intertendinous, submucous and subserous tissues, the fascia, periosteum and nerve sheaths; less frequently the kidneys, breasts, uterus and ovaries (Borst).

A special form of the hard fibroma is that which develops from the periosteum of the jaw and appears as a hard slowly growing tumor beneath the buccal mucosa. Such a fibroma is called an *epulis*, or by some a *fibroid epulis*, to differentiate it from sarcomatous growths of the same region to which the term epulis is sometimes improperly applied.

Keloid or Cheloid.—The peculiar condition called keloid occupies a position which in many respects is intermediate between that of the true fibroma and of a chronic inflammatory fibrosis. It is probably not a true neoplasm. Keloid is a dense fibrous subcutaneous growth rising above the surface and covered with stretched skin. It occurs in linear or lobulated masses, often overlapping the surrounding structures. The older writers described two forms, a true, or spontaneous, and a false, or cicatricial keloid. It is now believed that in practically all cases keloid is secondary to some trauma which, however, may be exceedingly slight. A racial and individual susceptibility is a prominent factor in the etiology, the colored race being particularly prone to the development of keloid. There is a slight tendency to spontaneous absorption after many years, but on the other hand, attempts at surgical removal are very often followed by recurrences more extensive than the original.

Fibroma Molle.—Soft fibroma, fibroma areolare. The fibroma molle is a soft white or reddish-gray tumor composed of a loose reticulum of connective-tissue cells and intercellular fibrillæ. The cut surface is usually well moistened by the abundant lymph content of the reticulum. Blood-vessels are as a rule richly supplied and the capillary net-work well developed. Mallory has found the same types of intercellular fibrils in the soft fibroma as in the hard fibroma and in mature connective tissue generally.

Soft fibromas are found especially in the cutaneous and subcutaneous connective tissue although they may occur wherever connective tissue is to be found. When localized in the submucosa a pedunculated growth may be formed. Occurring subcutaneously such a fibroma may result in a fibroid wart, if submucous, a fibroid polypus. The latter are especially common in the nose and nasopharynx but by no means all nasal polypi are fibromas. Oftentimes it is a difficult matter to say from the microscopical section whether a given nasal tumor is the more common inflammatory polyp, more or less self-limited in its growth, or whether it is a true fibroma which may continue its expansive growth until it produces pressure atrophy of the bone and breaks through into the cranial vault.

In both the fibroma durum and fibroma molle certain *retrograde changes* are occasionally to be found. These are the more common in large tumors which have areas to which the blood supply has been more or less completely cut off. Such areas may show *simple necrosis* or there may be *liquefaction necrosis* of the dead tissue with the subsequent formation of cysts. In the absence of liquefaction, cholesterin crystals may be found in abundance in the masses of tissue débris. *Calcification* may result from the deposit of lime salts either in necrotic areas or more diffusely scattered among the fiber bundles. Such deposits of lime salts are sometimes mistaken for bone, but *true bone formation* undoubtedly does occur in fibromas as a metaplastic process just as it does in dense connective tissue of chronic inflammatory origin elsewhere in the body. The denser fibromas frequently show a marked formation of connective-

tissue *hyaline* although this is more common in certain of the mixed types. On the other hand, a *mucoid change* (*fibroma mucinosum*) is frequently noted in a soft fibroma and then differentiation from a myxoma may be difficult. *Fatty change* is rare in fibromas.

Very cellular fibromas may undergo a *malignant change* into fibrosarcomas or even small spindle-celled sarcomas. It is impossible to know how frequently this happens but it is probably rather rare. In the microscopical examination of simple fibromas areas

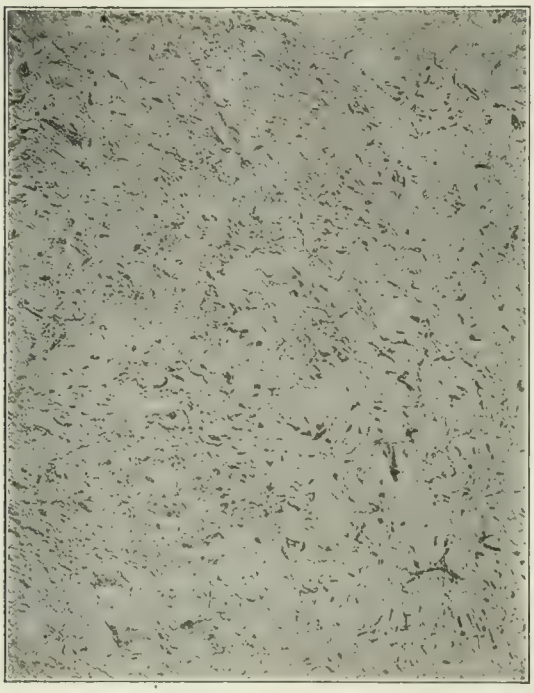

Fig. 2391.—Fibroma Molle. Section from a very soft and edematous tumor. Stained with Delafield's hematoxylon and eosin. Zeiss obj. "B."

sufficiently cellular to be considered sarcomatous are not often met with, but the relationship between the fibroma and the fibrosarcoma is so close that this possibility must be borne in mind. It is probable that the two forms should be considered together as a tumor entity with rate of growth as the chief differential point between them.

As to its *clinical significance* the simple fibroma is essentially a benign tumor. It is usually encapsulated and its habit of growth is always expansive and never infiltrative, and the true fibroma never gives rise to metastases. In like manner, the true fibroma does not recur after removal of the growth and of the area from which it arises. The so-called "recurrent fibroid" of the abdominal wall has been shown to be sarcomatous in some cases and in others subject to recurrence only because of incomplete removal. Although benign as far as infiltrative growth and metastasis are concerned, the fibroma may under certain conditions prove deleterious or destructive to the life and health of the individual. Through pressure upon neighboring structures, vascular disturbances may arise or injuries to nerves may be produced. Atrophic and degenerative changes in the organs pressed upon are the rule. The necrotic fibroid may poison by its toxic products and the sloughing, bleeding fibroid may give rise to a severe secondary anemia.

As to the necessity for surgical removal, each case must be considered upon its own merits. If the neoplasm impairs the health of the individual, or if, through sudden increase in rate of growth or otherwise, there is suspicion of malignant change, thorough excision should be strongly advised.

Mixed Fibroma.—The mixed fibromas are much more frequently met with than are the simple types. In many cases, however, it is exceedingly difficult to decide whether the connective-tissue proliferation is truly neoplastic or whether it is induced by the presence and activity of other blastoma. Unless the former is the case, the word "fibroma" should not be used in naming the tumor. It is for this reason that many terms, such as *fibrocarcinoma*, are being discarded. For still another reason the group of mixed fibromas is one of uncertain scope. Many of these tumors are more properly considered under the title of the complicating neoplasm, but because they are called *fibroids* by the clinician it seems best to give them mention here. The most important of these is the *leiomyofibroma* or *uterine fibroid* which is more properly considered a leiomyoma rather than a fibroma. Adami has called attention to the fact that these tumors when young are almost if not quite purely myomatous while the fibrous tissue increases in proportion to the age and size of the growth. The leiomyofibroma occurs as single or multiple tumors, affecting the body of the uterus more frequently than the cervix. According to location these tumors are described as submucous, interstitial or subserous

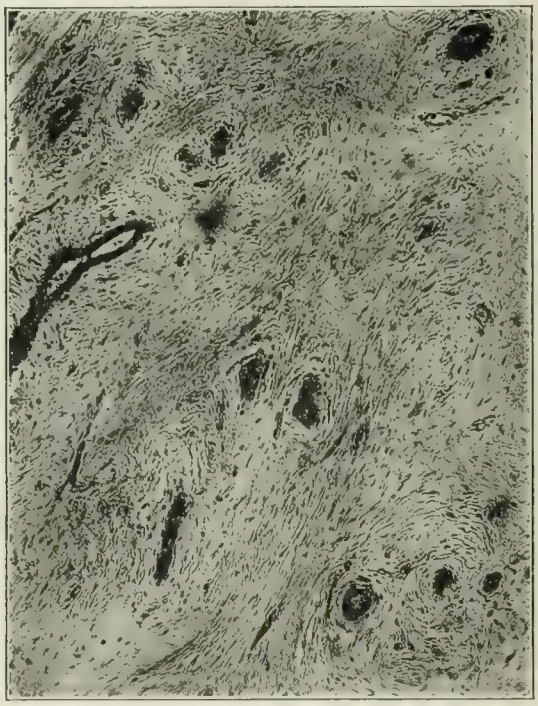

Fig. 2392—Pericanalicular Adenofibroma of the Breast. Stained with Delafield's hematoxylon and eosin. Zeiss, obj. "B."

They frequently become pedunculated and may then extend either into the peritoneal or into the uterine cavity, depending upon their original site. The larger growths, when cut across, have much the same appearance as the fibroma durum. The degenerative changes which have been mentioned above as occurring in fibromas are nowhere better seen than in this mixed type. Hyaline degeneration is especially common. The leiomyofibroma is entirely benign as far as either infiltrative or metastatic growth is con-

cerned, but it may provoke uterine hemorrhages, become secondarily infected, undergo sarcomatous change, or otherwise prove harmful. (See *Myoma* and *Uterus, Tumors of the.*)

The *adenoleiomyofibroma* occurring in the wall of the Fallopian tube or in the posterior uterine wall is called also *von Recklinghausen's tumor.* Like the preceding type, it is more properly considered with the leiomyomas, from which it differs chiefly in having gland-like structures scattered through it.

The combined adenomatous and connective-tissue tumors of the breast are properly placed with the mixed fibromas. When the fibrous elements predominate such tumors are called *adenofibromas,* while if the glandular proliferation is the more important they should be called *fibroadenomas.* These are the most common mammary gland growths and are of great importance because of the possibility of their glandular elements undergoing carcinomatous change. They occur as firm spherical or nodular masses which may vary in size from that of a pea to larger than an egg. They are usually single but it is not at all rare for them to be primarily multiple in one or both breasts. The adenofibroma of the breast is most common in the years between twenty-five or thirty but may be noted much earlier. Pregnancy and lactation have an unfavorable effect upon such tumors, oftentimes stimulating them to much more rapid growth.

Fig. 2393.—Intracanalicular Adenofibroma of the Breast. Stained with Delafield's hematoxylon and eosin. Zeiss obj. "B."

Dependent upon the general structural arrangement of the glandular spaces and the fibrous tissue, two chief types of adenofibroma of the breast are recognized. Very frequently the proliferating connective tissue is formed in concentric whorls about the acini and ducts. Thus the glandular structures come to be widely separated from each other and each duct appears to be compressed by the encircling mass of fibrous tissue. To such a growth the descriptive term of *adenofibroma pericanaliculare* is applied. In the contrasting type the connective-tissue proliferation is more sharply localized at points beneath the epithelial lining of the acini and ducts. Developing here, it pushes polypoid processes into the lumina which may become reduced to branching slit-like spaces. This type is described as the *adenofibroma intracanaliculare.* These two types are frequently associated in the same tumor. Cystic acini and dilated ducts are frequently found in the adenofibromas of the breast and when this condition is marked the special term of *adenofibroma cysticum* is applied.

The *myxofibroma* results from the combination of a myxoma with a fibroma, usually a fibroma molle. This term should not be employed when the myxomatous tissue is merely a degenerative process in a previously existing fibroma. The true myxofibroma is found especially in the nervous system (Hertzler).

Lipofibromas, combining fatty and fibrous connective-tissue tumors, are most often found in the subcutaneous tissue where they may attain an enormous size. True lipofibromas are not very common, for many of the growths assigned to this group have in reality been lipomas with thick fibrous septa and not neoplastic except in respect to their fatty constituent.

Neurofibroma.—Under this title it has been customary to describe a group of multiple tumors found in the subcutaneous tissue and along the larger nerve trunks. Such growths have been called, also, fibroma, molluscum fibrosum, fibromatosis nervorum, and neuroma, but are best known as von Recklinghausen's disease. These multiple tumors were first described by von Recklinghausen in 1881 as neurofibromas, but seventeen years later he concluded that the connective-tissue sheaths and the endoneurium were alone concerned in the formation of these neoplasms and that they therefore should be called fibromas. Since the original terminology still prevails in the literature these tumors should be mentioned here, but in more recent years Verocay and others have shown that many of these growths are primarily derived from a neurogenous tissue and that they are therefore not fibromas but, as Adami terms them, neurinomas. Whether this is true of all the tumors which have been described under the titles above listed is still a matter of controversy.

Carl Vernon Weller.

Ficus.—Fig.—The partially dried fruit of *Ficus carica* L. (fam. *Moraceæ*) (U. S. P.). This fruit can scarcely be regarded as a medicinal substance, though nutrient, and, like most sugary fruits, slightly laxative. It is retained in the Pharmacopœia merely because of its entering into the *Conjectio Sennæ,* but it seems likely that both it and the latter will shortly be dropped. Figs are commonly combined with purgatives. One method is to turn them inside out and stuff them with senna leaves, the mass being then chewed and swallowed. Figs grow upon a large shrub or small tree, native of the Orient, but cultivated in all warm countries, being hardy, with slight protection, as far north as Philadelphia. The dried fruit consists of nearly two-thirds its weight of sugar, some fat and gum, and small amounts of laxative salts. It is decidedly nutritious and has been known, in the fresh state, to constitute the chief food of armies for short periods. Besides the varieties distinguished by the names of the places from which they are exported, as Smyrna, Turkey, Greek, Marseilles, etc., figs are imported in two forms, known as "pulled" and natural. The former are rolled and kneaded until their structure is broken up and they have become soft and pliable; the solidly packed, layered, flattened figs are of this sort: the others are simply dried in the natural condition. These are oblong, rounded, and longitudinally wrinkled.

Henry H. Rusby.

Field of Response.—See *Heart, Functional Disorders of.*

Fifth Disease.—See *Erythema Infectiosum.*

Figwort.—See *Scrophulariaceæ.*

Filaria.—A genus of round worms of somewhat doubtful definition. Body filiform; anterior extremely attenuated, obtuse; posterior more attenuated than anterior; cuticle with or without transverse striation, without or with bosses. Stiles has split up the genus into a number of groups, or subgenera. Most species are blood parasites and are carried by mosquitos and other arthropods. See *Trematoda.*

A. S. P.

Filariidæ.—A family of long filiform worms with uniform diameter. The head is straight with two lateromedian and four submedian papillæ; mouth terminal, with two lips and occasionally a buccal capsule; esophagus without posterior bulb. Males with one or two unequal spicules and a spirally recurved tail provided with papillæ; females larger than males, uterus usually double. Important genera are *Filaria, Loa, Hamularia, Microfilaria,* and *Agamofilaria.* See *Nematoda.* A. S. P.

Filix Mas.—See *Aspidium.*

Finger-prints.—See *Anthropometry.*

Finsen, Niels Ryberg.—The inventor of the special application of light rays in the treatment of lupus and other diseases of the skin was born at Thorshavn, the capital of the Faroe Islands, on December 15, 1860. He obtained his early education in Iceland and was then sent to the University of Copenhagen, when he took his medical degree in 1890. Immediately after graduation he was appointed professor of anatomy in the Surgical Academy in Copenhagen but resigned after two or three years, as he had already become interested in the physiological and therapeutic action of sunlight and wished to devote all the time which the demands of a medical practice gave him to further study and research along that line. His first publication on light therapy was an article in *Hospitalstidende* on the treatment of smallpox by red light. Next he took up the study of the irritant effects of light on the skin, and in 1896 published a brief monograph on the treatment of lupus by the chemical light rays. In 1895 an Institute for the light treatment of lupus and other diseases was established in Copenhagen, this being the first of a number of Finsen light institutes and hospital installations in various parts of the world. The value of Finsen's work was recognized by the award of the Nobel prize of $40,000, one-half of which he gave to the Light Institute which he had founded.

For several years before his death Finsen was a sufferer from valvular disease of the heart with ascites and dropsy, but continued to direct the work of his Institute up to within a few days of the end which came September 4, 1904. Among his writings on the subject of phototherapy may be mentioned the following: "The Use in Medicine of Concentrated Chemical Light Rays" (in Danish), Copenhagen, 1896; "La Photothérapie," Paris, 1899; "Ueber die Bedeutung der chemischen Strahlen des Lichts für Medicin und Biologie," Leipsic, 1899; "A Note on Light Baths," *Journal of Physical Therapeutics,* 1900.

T. L. S.

Fission.—(L. *fissio,* a cleaving, from *findere,* to split.) Fission is a process of multiplication in which the parent organism divides into two daughter organisms approximately equal in size and development; as distinguished from budding, in which the parent remains intact and the daughter organism is a new individual formed by a small outgrowth upon the parent. (See article *Budding.*)

Ordinary cell division is a process of fission, and, consequently, this is the usual method of reproduction among the unicellular organisms. The yeasts and some of the Protozoa, however, reproduce by a process more accurately described as budding. But the Bacteria, Protophyta, and nearly all of the Protozoa multiply by fission and often with almost incredible rapidity. In the simpler forms there are no preparatory changes other than those ordinarily associated with cell division in these groups. But in the more highly differentiated Infusoria provided with permanent oral funnels, ciliated bands, etc., these structures may be duplicated in the two new individuals previous to their separation, a process analogous to what takes place in many multicellular organisms.

In the Bacteria fission is transverse. The Protozoa presents several types of fission: longitudinal fission is characteristic of the Mastigophora, and transverse fission of the Ciliata; while in many Sporozoa may be witnessed the process of multiple fission, or schizogony, in which the nucleus of the cell divides repeatedly and subsequently the cell divides into as many parts as there are nuclei. The question as to whether *Treponema pallidum* multiplies by transverse or by longitudinal fission has been conspicuous in the discussion of the affinities of this important organism, whether with the Bacteria or with the Protozoa.

The multiplication of individuals by fission is unknown among plants above the very simple Schizophyta.

Among the Metazoa, on the other hand, this method of multiplication is common in some of the lower orders and may occur abnormally in so high a group as the vertebrates.

In a few cases fission occurs without any previous preparation. The adult animal tears its body apart by its own efforts. A wound is formed by the rupture of the tissues with a loss of the fluids of the body. This wound heals, and from its surface the missing parts of each of the new individuals are regenerated. The method has been observed in the genus Hydra, in two annelids, Lumbriculus and Ctenodrilus, in certain star-fishes and ophiurans. In the latter the plane of fission passes through the disc dividing the mouth and the stomach, while to one part of the disc three arms remain attached, to the other, two; and each half regenerates the missing parts. But in one family of star-fishes, the Linckiidæ, the process is somewhat different. Here the five arms separate from the disc and then the disc regenerates five new arms, and each detached arm regenerates a disc and four new arms. Delage relates that he observed once the division of a sea anemone, *Anthea cereus.* The two parts of the body were extended as if trying to crawl in opposite directions. The intermediate portion became much constricted and finally ruptured. The whole operation occupied about two hours.

On the other hand, in most animals in which fission is a normal process of multiplication, it is preceded by preparatory changes which result in each of the new individuals being provided with a full complement of organs before separation takes place.

According to Parker, fission in the common sea anemone of the coast of New England, *Metridium marginatum,* is a slow process occupying many months. It begins with the division of the mouth and oral disc accompanied by the formation of new septa, and proceeds gradually toward the base. The final separation has not been observed, however.

In many worms fission takes place in what may be regarded as a larval stage, before the development of eggs and spermatozoa. This, according to Mensch, is the case with Autolytus, and it seems to be so with most of the worms in which fission occurs. In Autolytus and its allies an area of embryonic tissue

appears in some species at about the thirteenth segment, in others at about the thirtieth segment, dividing the young worm into two parts. On the posterior part there is developed a new head. The tissues just in front of the head undergo degeneration, and by their own movements the two individuals are broken apart. Before this separation takes place, however, the embryonic tissue may give rise to a new individual, and this process may be repeated until there is present a chain of zooids, or stolons, the youngest individual in the chain being attached to the posterior end of the parent stock.

Among the jelly-fish of the group Scyphomedusæ fission is associated with the metamorphosis from the larval to the adult form. In Cassiopea, for example, the scyphistoma larva is a graceful little creature shaped like a wine glass and lives attached by its base to some solid body. When fully developed this larva becomes divided into two portions by a horizontal constriction. It is then called a strobila. The upper part of the strobila becomes transformed into a medusa, while new larval tentacles and the rudiment of a proboscis are developed on the lower part. Finally the narrow isthmus connecting these two parts undergoes degeneration and is at length ruptured by the violent swimming movements of the young medusa.

Fission may take place in an early embryonic stage of development. According to Kleinenberg this occurs normally in one of the earth worms, *Lumbricus trapezoides*, in which the embryo divides into two shortly after the gastrula stage and both develop into normal individuals. This has been observed to occur under abnormal conditions in the trout and the chick. If hen's eggs be incubated at a temperature slightly above normal a large proportion of the embryos will be found to show a tendency to the formation of double monsters and occasionally the area embryonalis will be found to contain two distinct embryos. A similar division of the embryo may occur in man. If incomplete, it will give rise to a double monster or to such cases as the Siamese twins and Millie-Christine. If the separation be complete the result will be a pair of twins of the same sex. In every case of fission all the individuals produced from a single ovum are of like sex.

In some of the lower forms of animal life fission may be normally incomplete, as in some corals, in which the individuals remain in organic union forming a colony, or cormus.

There are some animals in which a form of fission occurs in the fully mature adult, which does not serve to multiply the individual but for a more favorable dispersal of the sexual products. The formation of proglottides by the common tapeworm is an example. Another example is the palolo worm of Samoa, an annelid that burrows in the coral rock. When mature the posterior portion of the body, distended with eggs or spermatozoa, is separated off and swims on the surface of the water, where the sexual products are discharged. The palolo worms appear at certain times in great abundance and are gathered by the natives, who relish them greatly as an article of food.

The relation between fission and budding is a very close one, so much so that Bock has argued that they are simply two forms of one fundamental process. In many sea anemones, for example, small fragments of the foot become detached and subsequently develop a mouth and tentacles and become complete individuals. Such cases make it difficult to draw a sharp line between fission and budding. In forms like Autolytus, mentioned above, the two processes are closely associated. For, after the original posterior part of the body is separated off, the embryonic area on the end of the anterior portion, or parent stock, may give rise to any number of new individuals by a continuous process of budding. Nevertheless in most cases the distinction between fission and budding is a clear one and is useful in practice.

ROBERT PAYNE BIGELOW.

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Fitz, Reginald Heber.—Born in Chelsea, Mass., May 5, 1843. After graduation in arts from Harvard College he entered the medical school, at the same time, as the custom then was, studying in the office of a practising physician. His preceptor was Dr. Jeffries Wyman, an eminent anatomist, who trained his pupil to be a close observer of men and symptoms. During a part of his medical course Fitz served as house physician at the Boston City Hospital, and

FIG. 2394.—Reginald Heber Fitz.

after taking his degree of M. D. in 1868 he spent two years in study in Europe, the greater part of the time being under Virchow in Berlin. From 1871-1882 he was physician to the Boston Dispensary; in 1871 he was appointed microscopist to the Massachusetts General Hospital and instructor in pathological anatomy at the Harvard Medical School; in 1873 he was made Assistant Professor, and in 1879 Shattuck Professor of Pathological Anatomy at the same institution; in 1892 he was made Hersay Professor of the Theory and Practice of Physics. He received many and deserved honors. Harvard University conferred on him the degree of LL.D. in 1905, and he was made an honorary member of a number of medical societies in this country and

Europe. In 1894 he was President of the Association of American Physicians, and in 1907 of the Congress of American Physicians and Surgeons. He died of chronic gastric ulcer at Brookline, Mass., on September 30, 1913.

Fitz was a trained pathologist, a brilliant practitioner, and a remarkably successful teacher. He was not a very prolific writer, but two contributions made by him to medicine established his fame as one of the most acute of observers. The first of these was a paper on "Perforative Appendicitis, with Special Reference to Diagnosis and Treatment," read before the American Association of Physicians on June 17, 1886. The second was a lecture on "Acute Pancreatitis," delivered before the New York Pathological Society in 1889. Both of these contributions were recognized at once as the work of an authority and they will remain among the imperishable medical classics. Fitz was also joint author with H. C. Wood of a treaties on "The Practice of Medicine," Philadelphia, 1897. T. L. S.

Flag, Blue.—See *Iris*.

Flag, Sweet.—See *Calamus*.

Flagellata.—*Euflagellata*. Mastigophora with one or more flagella. Many species are colonial. This subclass of protozoans contains many parasites. See *Protozoa*. A. S. P.

Flatulence.—This is a condition in which gas is conspicuous in the alimentary canal. The word flatus is applied to gas itself, as expelled. Without qualification, both flatulence and flatus apply to the intestine rather than the stomach, and to the expulsion of gas through the anus in troublesome amount. Tympanites is the corresponding expression from the static standpoint, referring to abdominal distention without relief by free escape of gas.

The gases of the bowel include as derivatives of swallowed air: nitrogen, possible vestiges of oxygen, small amounts of carbon dioxide and the rarer atmospheric gases. Carbon dioxide is due mainly to the effervescence between the acid gastric contents and the carbonates of the biliary, pancreatic, and intrinsic intestinal secretions; the amount due to this source being one to three liters a day; it is produced to a greater or less extent in all forms of microbic action; it was formerly ascribed to elimination from the blood, analogous to pulmonary expiration, but it is doubtful whether any considerable amount is due to this source. Hydrogen and methane are due to the breaking down of indigestible cellulose by saprophytes, also to the fermentation of digestible carbohydrates, rancid decomposition of fats and perhaps putrefaction of proteins. Hydrogen sulphide is sometimes designated as an abnormal constituent but is practically always present from the decomposition of certain proteins or is more directly derived from such active principles as ethyl sulphide and, with it, methyl mercaptan, less often ethyl mercaptan and ethyl sulphide may be associated. These sulphides unite with carbon dioxide to form carbon disulphide, with water and alcohols as by-products.

Various volatile organic acids and esters are produced from carbohydrates and fats or represent volatile constituents of foods, as allyl sulphide from onion and garlic. Protein decomposition is also attended by the formation of small amounts of ammonia.

Incubation of the alimentary contents yields gas to a less degree, and less frequently in appreciable degree than is usually believed. Stomach contents of more than ten degrees (decinormal) of free hydrochloric acid, rarely yield more than a few bubbles of gas and even in achlorhydria and in distinct achylia, gas is absent or insignificant in amount in a surprising number of cases. Feces, either originally liquid or brought to this consistence by dilution and emulsification, usually show only a few bubbles up to five or ten per cent. of gas by volume. They may, however, yield 100 per cent. or more, sometimes blowing off the tops of their containers or rising like bread sponge or foaming like beer, by spontaneous fermentation at room temperature. Owing to the time limits and other circumstances applying to stomach contents, even when obtained by vomiting, it may usually be held that if the material does not yield gas by prolonged fermentation, it cannot have done so in the stomach—the only notable exception being that fermenting food may have this action inhibited by hydrochloric secretion. On the other hand, as feces are the residue of intestinal activity obtained only after a long delay, the analogous conclusion is not warranted. But it may safely be held that if either stomach contents or feces yield gas by experimental incubation they have probably done so in the alimentary canal.

In estimating tympany and flatulence, it must be remembered that considerable gas is necessary for the proper performance of the motor function of the alimentary canal; the intestine, especially, may be said to float upon itself in the abdominal cavity. Without undue formation of gas, from any cause, tympany may result from undue relaxation of the general musculature of the alimentary canal, from spasm of sphincters including that of any ring of circular muscular coat of the bowel or from any organic cause of constriction or occlusion or from any condition resulting in the stoppage by contents. On the other hand, a marked increase of general muscular tone or a relaxation of sphincters, may result in flatulence. For instance, with the same and perhaps not abnormal introduction of gas into the stomach, one patient may complain of distention—the subjective expression of tympany—because of contracted pylorus and cardia while another complains of gulping up gas—gastric flatulence—for the opposite reason. Similarly, for the intestine, one patient may complain of what is vulgarly called "confusion of the wind," the gas wandering up and down the intestinal canal on account of lack of expulsive power while another complains of the embarrassment of flatulence. So, too, the complaint in the latter case may be due merely to tonicity and accidental conformation of the sphincter, which cause audible discharge, or with regard to odor, the latter condition alone having anything to do with underlying conditions of gas production. Conditions resulting in tympany, with or without occasional flatulent discharge, due to obstipation and to inflammatory and other pathologic conditions mainly of a surgical nature, will not be considered here. It may be mentioned, however, that the detection of some volatile oil as of peppermint, in the flatus, may be a valuable sign that the intestine is not completely obstructed.

In the absence of gas by prolonged (twenty-four hours') incubation of stomach contents, gastric flatulence or tympany may be due to ordinary air-swallowing, to true aerophagia or to effervescence between acid gastric contents and carbonatic intestinal secretions already discussed under aerophagia; also to ingestion of carbonates or charged waters and rarely to true fermentation of food due to original contamination with yeasts and bacteria or to their passage through a foul mouth, subsequent fermentation being prevented by hydrochloric acid secretion. The differential points and methods of prevention are obvious.

If gas is developed in the stomach contents by incubation, the tympany or flatulence is reasonably ascribable to fermentation, hydrochloric acid being practically always much reduced, unless under circumstances which allow fermentation in spite of a moderate amount of HCl, as initial infection of the food with yeasts or bacteria, gastric stagnation, etc.

The indications for treatment are to use freshly cooked food, or at least fresh and clean food, to avoid oral sepsis and to attend to carious teeth and foul tonsillar crypts; to supply HCl, to stimulate gastric secretion and motility by strychnine, endogastric sprays, to cleanse the stomach by lavage and to allow long intervals of rest between meals.

In the absence of definite obstruction or failure of normal intestinal peristalsis, tympany of the bowels is practically always due to increase of gas by microbic action. Excepting a theoretic standard, flatus is practically always an occasional phenomenon, even in health, the gas is not always passed without noise or embarrassment and it is practically never odorless and it may be highly offensive, normally, from the use of onions, garlic, etc., or even from the inevitable production of the sulphurous gases on a diet containing sulphur proteins. Flatulence is sometimes described as a nervous phenomenon and as especially characteristic of hysteria but, aside from heightened peristalsis on the one hand or imperfect control of the sphincter on the other, a true excess of either tympany or flatulence is, in such cases, strictly due to fermentative and putrefactive processes.

The most common cause of a marked excess of intestinal gas is an excessive development of yeast, easily demonstrated microscopically, while the feces may be of the consistence of bread sponge, rising with bubbles of gas, or, if more liquid, developing a bead like beer, the gas being chiefly carbon dioxide.

Whether *Bacillus aërogenes capsulatus* is a normal denizen of the intestine, whether it is identical with *Bacillus enteritidis sporogenes* or *Bacillus perfringens*, and whether as an intestinal saprophyte, it produces large amounts of gas, are *sub judice*. A large number of intestinal bacteria produce gas. Their classification, the exact chemistry of their production of gases, the specificity of their action on different proximate nutritive principles, the relation of the degree of gas production to numeric increase of particular species on the one hand or to differences of virulence on the other, are not well known.

Speaking generally, the putrefaction of proteins is due mainly to anaërobes, the characteristic gases produced being ammonia and hydrogen sulphide or methyl mercaptan or, occasionally ethyl mercaptan or ethyl sulphide. Carbon dioxide is also produced from proteins. By the secondary combination of the sulphurous gases with carbon dioxide, carbon disulphide is formed. This gas, being somewhat less volatile, gives a characteristic after-smell to flatus.

In the fermentation of digestible carbohydrates and fats, much carbon dioxide, some hydrogen and volatile organic acids are produced, the odor of the flatus being pungent and sour. In these two forms of gas production, the gas is not, as a whole, inflammable.

Cellulose is not digestible but is largely destroyed by bacteria, with the production of methane and hydrogen. If this type is marked, both tympany and flatulence are conspicuous and the flatus is inflammable—a fact known to many children and possibly accounting for mysterious burns. One of the writer's patients, going to an out-door closet after dark, dropped some lighted paper down the hole, and as defecation was preceded by a copious discharge of gas, an explosion occurred which raised him from the seat and produced painful burns. The writer has never been able to light the intestinal gas at necropsies, perhaps because the diet for some time before death would naturally be limited as to cellulose, perhaps because of the absorbability of the more inflammable hydrogen and methane or the development of an excess of carbon dioxide.

These types of intestinal gas production are not sharply limited from one another but are often sufficiently so for clinical purposes. In that case there is an obvious indication to change the diet by excluding so far as possible the principal food ingredient attacked by bacteria. If the ammonia-sulphurous type occurs, buttermilk or preparations of lactic acid bacilli are especially indicated, just as they are strongly contraindicated, but often indiscriminatingly used, in cases of carbon-dioxide excess with sour volatile products.

Feces are stated to contain a tenth to a third of bacteria by dried weight, many of the bacteria being still alive. While absolute sterilization of the intestine is impossible, and probably undesirable, there is a plain indication for wholesale elimination of bacteria by purgation, calomel, and castor oil being on the whole, preferable. Thorough cleansing of the lower bowel by enema is also often necessary. When an additional indication for more or less permanent laxative action is present, cascara, phenolphthalein, pure mineral oil, and bile, stimulated by administration of inspissated bile or biliary salts or salicylic acid, are the remedies of choice. Dietetic laxatives such as molasses, prunes, figs, vegetable and animal oils, and fats, and vegetables rich in cellulose are usually contraindicated because of their action through producing fermentation and hence gases, unless in opposing a clear type of fermentation of a different kind.

A certain amount of gas may be fixed by adsorbents, of which the chief are kaolin and charcoal. The latter should be of animal origin, by preference, thoroughly dry and should be given in adequate dose, say a coffee-spoonful, three times a day. Small amounts, in moist tablets, are useless.

Errors of digestion, as well as of diet, must be determined by analyses and met so far as possible.

While internal antisepsis is scorned by bacteriologists and should not be relied upon to the exclusion of the preceding measures, there is no question but that it does reduce either the number or virulence of intestinal saprophytes so as to have an appreciable influence on tympany and flatulence. Among the drugs that have been found satisfactory, with these qualifications, may be mentioned menthol, various volatile oils, salol, which should be used cautiously, salacetol, aspirin, acetozone. In the writer's experience, combinations of the salicylic-acid radicle have proved superior to those of the benzoic-acid radicle, and safer than combinations of phenyl which adds the element of danger to salol. As an antiseptic, bismuth salicylate is to be preferred to other bismuth salts although all seem to have some value in this way. If there is also diarrhea, copper may be employed. If this contraindication does not exist, arsenic may be given and it may be questioned whether the hematinic action of arsenic is not due rather to its prevention of the formation of hydrogen sulphide, etc., in the intestine than to any direct action on the blood.

A. L. Benedict.

Flaxseed.—See *Linseed*.

Fleas.—*Siphonaptera*. Diptera (?) with laterally compressed bodies and distinctly separated rings. Wings absent, except for two lateral plate-like appendages on the mesothorax and metathorax. These animals carry various diseases, notably the plague, certain blood parasites, and larval cestodes. See *Insects, Parasitic*. A. S. P.

Fletcher, Robert.—Born in Bristol, England, March 6, 1823. His medical education was obtained in the Bristol Medical School and Infirmary and at the London Hospital. In 1844 he became a member of the Royal College of Surgeons and a licentiate of the Society of Apothecaries. In 1847 he came to America and practised for a number of years in Cincinnati. When the Civil War broke out he entered the Union Army and served in the medical corps where he was brevetted Colonel. In 1871 he

was ordered to Washington to assist in the preparation of the Anthropometric Statistics of the Provost-Marshall's office; in 1876 he was attached to the library staff of the Surgeon-General's office under Dr. John S. Billings, and remained in that position until his death which occurred on November 8, 1912.

Dr. Fletcher's great service to medicine was as a bibliographer and the medical world owes to him many volumes of the Index Catalogue of the Surgeon-General's library and of the Index Medicus, begun by Billings and continued by Fletcher. He was especially interested in anthropology and in medical history, as the following partial list of

Fig. 2395.—Robert Fletcher.

titles of monographs and essays bears witness. "Trephining and Cranial Amulets," "Human Proportion in Art and Anthropometry," and "Tattooing among Civilized Peoples," 1883; "Myths of the Robin Redbreast in Early English Poetry," 1889; "The New School of Criminal Anthropology," 1891; "Anatomy in Art" and "Medical Lore in the Older English Dramatists and Poets," 1895; "The Witches' Pharmacopœia," 1896; "Scopelism," 1897; Tragedy of the Great Plague at Milan in 1630," 1898; "Columns of Infamy" and "Some Diseases Bearing the Names of Saints," 1912.

In 1910 the Council of the Royal College of Surgeons of England conferred upon Dr. Fletcher the honorary medal of the College for "distinguished labors eminently conducive to the improvement of natural knowledge and the healing art." The medal is rarely conferred, and had been given to only eleven others, among whom were Parkinson, Paget, and Lister. T. L. S.

Flint, Austin.—Born in Petersham, Mass., October 12, 1812. He came of a race of English and American physicians, his great-grandfather, grandfather, and father all having been medical men, and all having obtained more than average eminence. He was educated at Amherst College and was graduated in medicine at Harvard in the year 1833. The first three years of the professional life were passed at Northampton and Boston. In 1836 he went to Buffalo, where he remained until 1844, his prominence at that time securing him a call to the chair of Institutes and Practice of Medicine at the Rush Medical College, Chicago. After a year of that life he returned to Buffalo, where he established the *Buffalo Medical Journal* in 1846, which he conducted for ten years. Meanwhile he was increasing his usefulness in various directions. He was one of the three founders, in 1847, of the Buffalo Medical College, at which, until 1852, he occupied the chair of the Principles and Practice of Medicine. Then he went to the Louisville University, holding the same chair in that institution, remaining there until 1856, when he went back to Buffalo as Professor of Pathology and Clinical Medicine. While still holding a residence at Buffalo he passed the winters of 1858, 1859 and 1860 at New Orleans, where he was Professor of Clinical Medicine in the medical school, and was also visiting physician to the Charity Hospital. He changed his home toward the close of this engagement to New York City. In 1861 he became one of the physicians to Bellevue Hospital and was appointed to two Professorships—the Principles and Practice of Medicine and Clinical Medicine at Bellevue, and Pathology and Practical Medicine at the Long Island College Hospi-

Fig. 2396.—Austin Flint.

tal. He remained always with the Bellevue Faculty, but his duties forced him to sever his connection with the Brooklyn college in 1868. In 1872 he was elected President of the New York Academy of Medicine, and in 1884 he was President of the American Medical Association. He was a member of a very large number of learned societies in this country and Europe. He died March 13, 1886.

Flint was an industrious writer as well as teacher. His "Treatise Upon the Principles and Practice of Medicine," first published in 1866, ran through seven editions. A work on "Clinical Study of Heart Sounds in Health and Disease," which he wrote in 1852, received the first prizes of the American Medical Association in 1852 and 1859. His work on "Phthisis," and his "Manual of Percussion, etc.," were long standard works. T. L. S.

Florida.—Twenty-five years or more ago Florida was perhaps the most popular winter resort in this country for the consumptive. He was sent there in all stages of the disease, especially in the more advanced ones. It was the final resource when all else failed, and, in the majority of cases, proved to be an illusive one.

At the present day it is rare that the phthisiotherapeutist directs his consumptive patient to this region, although possessing a winter climate unexcelled in many of its characteristics by any region east of the Rocky Mountains. Why is this? In a word, it is because we now have a truer conception of the limitations of climate, in its application to pulmonary tuberculosis. The hygienic-dietetic treatment is the authoritative one, established on the firm foundation of experience; and in the execution of this treatment climate is but one factor, and perhaps not the most essential one. Formerly climate was supposed to be the great determining element in the treatment and all else was merely accessory; and further, a warm climate was considered to possess peculiar advantages for the consumptive.

It is natural that such should have been the idea entertained with the knowledge of the pathology of the disease then obtaining, and before the results of Brehmer and other German pioneers in the sanatorium treatment had become known or had indeed been determined. What more natural than that a consumptive depressed in mind and body should look to a warm, sunny, equable climate, with its semi-tropical attractions, as the El Dorado from whence he should receive renewed hope and health? Although Florida will continue to be a great and a popular health resort for many functional and organic diseases, and for the valetudinarian in general, as will be more fully discussed later, it also, in the writer's opinion, offers certain locations situated in the central part of the peninsula, such as Winter Park, Orlando, and Altamonte, which possess some at least of the essential climatic conditions for the successful accomplishment of the hygienic-dietetic treatment of tuberculosis, particularly in the colder months of the year, for experience has shown that a cold or moderately cold climate gives the best results in the treatment of pulmonary tuberculosis.

As with all tropical or semi-tropical countries, however, the summer climate of Florida would hardly admit of a continuous residence, which is, in many cases at least, essential.

The State of Florida may be described as consisting of a continental portion, immediately contiguous to the States of Georgia and Alabama—its southwestern portion washed by the Gulf of Mexico—and a peninsula portion washed by the Atlantic Ocean and Gulf of Mexico. Keating (Transactions of the American Climatological Association, 1885) divides Florida geographically into a north and a south portion, the boundary line being the twenty-ninth degree of latitude, and topographically into the lowlands on the rivers and coasts, and the interior highlands, with an altitude of from 100 to 300 feet. Below the twenty-ninth parallel, the climate, both in summer and in winter, differs from that of the region north. The cold northwest winds are tempered by the warm waters of the Gulf of Mexico, which prevent the sudden changes of temperature that sometimes occur in the northern portion. In summer the sea breezes from both sides of the peninsula temper the heat and the nights are generally cool (Solly).

The land (except the interior highlands before mentioned) is for the most part low, and there are many lakes, streams, and salt-water channels. The principal river is the St. John's, running north, and navigable for large steamers a distance of 198 miles to Enterprise, and for smaller ones about seventy miles further up the river, to Salt Lake. The soil is "as a rule sandy, very porous in hilly or undulating sections, but finer and more compact on level reaches. The character of the subsoil hard-pan varies greatly in different localities, being sometimes clay and sometimes lime rock, at variable depths of from only a few to ten or more feet from the surface" (J. P. Wall, in the *Climatologist*, October 15, 1891).

The varieties of land are the pine land in the highlands, high hummock, low hummock, savanna, and swamp. "The pine-land regions are those in which the sandy soil predominates, and, for the residence of invalids, places possessing such sandy soil appear to be the most healthful" (Richards).

The climate is a mild, moist, warm one, with a goodly number of sunny days. The principal season begins in January and lasts until April, and thousands of visitors who desire for any reason to avoid the inclemency of a Northern winter and lead an outdoor life, frequent the numerous resorts. Enormous palatial hotels and many boarding houses and villas exist in various portions of the peninsula, at St. Augustine, Palm Beach, Tampa, Palatka, Altamonte, Magnolia, Enterprise, Titusville, and at many other places. The attractive spots where one may pleasantly spend the winter are almost innumerable. The outdoor attractions in this fascinating country are varied and numerous—fishing, hunting, bathing, golf, sailing, riding, and all the many excursions by water, chief of which is the famous journey up the Ocklawaha River, where one passes through cypress forests with the graceful hanging moss, or through clusters of palm and palmetto trees, and all the varied vegetation of a tropical region. Alligators are frequently seen, and "birds of the most curious forms and brilliant plumage are everywhere conspicuous" (Appleton's "General Guide to the Southern States," 1899).

The orange groves are always a delight; and the cultivation of the many fruits, flowers, and vegetables which grow so luxuriantly in this climate render outdoor life on the land a constant source of pleasure and interest. "The sun shines so brightly, the air is so balmy, the songs of the birds are so enlivening, and the orange trees in their bloom, or laden with their golden fruit, lend such a charm to the outlook from the windows that the most indolent or most cold-blooded invalid feels little inclined to stay indoors" (Lente).

The climatic characteristics will now be considered somewhat in detail, and for this purpose the following meteorological tables have been arranged from the observations of the United States Weather Bureau.

AVERAGE TEMPERATURE.

	December.	January.	February	March	July	Year.
Jacksonville..	55.8	55.8	58.1	62.7	82.5	69.2
Jupiter.....	67.2	63.4	66.7	68.8	80.5	73.4
Tampa....	62.2	58.6	63.1	66.4	81.5	71.6
Punta Rassa.	64.5	64.7	66.2	68.6	81.3	73.4
Key West...	70.1	70.3	71.8	73.6	84.0	77.5

AVERAGE DAILY RANGE

	December.	January.	February.	March.	July.	Year.
Jacksonville...	17.0	16.7	16.4	17.4	16.1	
Jupiter.....	12.2	15.0	13.4	14.0	12.2	12.6
Tampa.....	18.0	19.8	17.1	18.9	16.1	17.7
Punta Rassa.	13.5	12.7	12.9	13.4	13.0	
Key West...	8.1	8.9	8.9	9.4	12.5	

MEAN OF WARMEST TEMPERATURE.

Jacksonville...	66.4	64.9	68.5	73.6	91.6	
Jupiter.....	73.3	70.9	73.4	75.9	86.6	79.7
Tampa	71.2	67.8	71.7	75.8	89.6	80.5
Punta Rassa..	71.9	71.3	73.2	76.1	88.9	
Key West...	75.3	75.4	77.1	78.9	91.3	

MEAN OF COLDEST TEMPERATURE.

Jacksonville..	49.4	48.2	52.1	56.2	73.5	
Jupiter.....	61.1	55.9	60.0	61.9	74.4	67.1
Tampa.	53.2	48.0	54.6	56.9	73.5	62.8
Punta Rassa.	58.4	58.6	60.3	62.7	75.9	
Key West...	67.2	66.5	68.2	69.5	78.8	

HIGHEST OR MAXIMUM TEMPERATURE.

Jacksonville...	81.0	80.0	83.0	88.0	104.0	
Jupiter	82.0	80.0	84.7	85.5	91.0	93.0
Tampa	81.3	78.1	80.5	84.2	93.2	94.4
Punta Rassa..	82.5	81.5	84.0	85.0	93.0	
Key West....	88.0	90.0	87.0	89.0	97.0	

Lowest or Minimum Temperature.

Jacksonville..	19.0	24.0	32.0	31.0	68.0	
Jupiter	41.0	38.5	39.8	44.8	69.1	32.7
Tampa	34.7	32.7	35.7	39.7	70.0	28.1
Punta Rassa.	34.0	33.0	43.0	38.0	67.5	
Key West....	44.0	48.0	55.0	53.0	72.7	

Average Relative Humidity.

Jacksonville...	73.7	74.6	70.6	65.4	71.8	72.0
Jupiter 8 A. M.	83.7	84.7	84.0	80.0	81.5	82.0
Tampa	83.4	81.6	83.8	80.0	82.4	81.2
Punta Rassa.	75.3	77.6	75.3	72.1	75.7	74.9
Key West...	78.7	79.7	76.6	70.5	70.3	73.9

Average Precipitation in Inches.

Jacksonville..	2.89	3.28	3.45	3.13	5.18	54.68
Jupiter.....	2.88	3.43	2.72	2.59	5.35	62.14
Tampa	1.57	2.45	2.81	2.68	7.99	53.09
Punta Rassa..	1.28	2.36	1.72	1.20	7.22	43.54
Key West...	1.84	2.32	1.84	0.66	4.27	40.88

Prevailing Direction of Wind—From—

Jacksonville...	N. E.	N. E.	N. E.	N. W.	S. W.	N. E.
Jupiter.....	N. W.	N. W.	S.	S.	S. E.	S. E.
Tampa	N.	N.	N. E.	S. E.	E.	N. E.
Punta Rassa..	N. E.	N. E.	N. E.	N. E.	E.	N. E.
Key West....	N. E.	N. E.	E.	E.	E.	E.

Average Hourly Velocity of Wind, in Miles.

Jacksonville..	6.0	5.8	6.9	7.9	6.3	6.7
Jupiter	10.2	9.9	10.7	10.6	7.6	9.7
Tampa.....	6.0	6.0	6.9	6.7	5.2	6.1
Punta Rassa.	10.3	10.2	10.7	12.0	8.2	10.1
Key West	11.2	10.8	10.4	11.2	7.5	9.7

Average Number of Clear Days.

	December.	January.	February.	March.	July.	Year.
Jacksonville..	10.2	9.0	9.7	12.7	10.2	123.2
Jupiter.....	9.8	13.0	11.0	17.4	12.5	131.4
Tampa	12.1	9.5	8.4	11.7	7.0	115.0
Punta Rassa.	12.1	9.8	11.5	14.7	3.4	102.9
Key West...	11.0	11.3	11.7	15.8	5.7	113.4

Average Number of Fair Days.

Jacksonville..	12.0	12.8	10.4	13.0	16.0	156.7
Jupiter	14.1	11.0	11.1	9.7	13.4	153.8
Tampa.	12.3	16.4	14.3	14.4	20.0	188.2
Punta Rassa.	12.8	15.0	11.4	11.8	10.4	186.1
Key West...	15.5	14.7	12.6	12.5	19.8	192.5

Average Number Clear and Fair Days.

Jacksonville..	22.2	21.8	20.1	15.7	26.2	279.9
Jupiter.....	23.0	24.0	22.1	27.1	25.9	285.2
Tampa.....	24.4	25.9	22.7	26.1	27.0	303.2
Punta Rassa.	24.9	24.8	22.9	26.5	23.8	289.0
Key West...	25.5	26.0	24.3	28.3	25.5	305.9

Five points are taken in various portions of the State to illustrate the different climatic factors: Jacksonville, on the St. John's River, about thirty miles from the Atlantic; Jupiter, on the Atlantic Coast, seventeen miles north of Palm Beach; Tampa, about twenty-five miles from the Gulf Coast, and about half-way down the peninsula; Punta Rassa on the Gulf Coast, almost opposite Palm Beach; and Key West at the extreme south, an island about sixty miles from the mainland.

In observing these climatic features the distinguishing characteristics are mildness and uniformity. It will be seen that the diurnal range for the coast stations is small, while that of Jacksonville and Tampa, further inland, is considerably greater, and least of all, as we should expect from its insular position, is that of Key West.

From the table of maximum and minimum temperatures it will be observed that for the four months from December to March inclusive the maximum ranges from 78.1° to 88° F., and the minimum from 19° to 44. 8° F.; Key West excepted. "There is a possibility then of frost, snow, and ice, although these phenomena are rare; they are the infrequent 'chances,' and occasionally a cold wave sweeps over the whole State, damaging or killing the orange trees, demanding fires indoors, winter clothing out." The relative humidity is high, characteristic of a marine climate, as this is, and is quite uniform throughout the year. "Of course, as might naturally be expected of a climate with the temperature and humidity of that of Florida, heavy dews in clear still nights are always present; and during the winter and spring, fogs in the night and early morning are not uncommon. Fogs are, however, somewhat worse on the Atlantic Coast and along the St. John's River than on the Gulf side of the peninsula" ("The Climate of Florida," Dr. J. P. Wall, the *Climatologist*, November 15, 1891). The mean annual rainfall may perhaps be considered high for a health resort, although about half occurs in the summer. For comparison the mean annual rainfall of various resorts is here given:

	Inches.		Inches
Jacksonville, Fla..	54.6	Aiken, S. C.....	48.0
Jupiter, Fla.....	62.1	Thomasville, Ga.....	51.5
Tampa, Fla.....	53.0	Augusta, Ga.....	44.0
Punta Rassa, Fla.....	43.5	San Diego, Cal.....	10.0
Key West, Fla.....	40.8	Los Angeles, Cal.....	18.0
Redlands, Cal.....	15.0	Santa Barbara, Cal.....	18.0
Denver, Col.....	14.4	Cannes, France.....	25.0
Nice, France.....	32.0	Cairo, Egypt.....	15.0
New York, N. Y.....	42.5		

The prevailing winds are from the east, bringing the pure air from the Atlantic Ocean. The hourly velocity is between six and ten miles, considerably less than that at Cape May. "With the Atlantic on the east and the Gulf of Mexico on the south and west the temperature of Florida, and especially that of the peninsula, is very much ameliorated by the constant sea breezes, and the climate rendered remarkably equable and genial. The regular alternation of land and sea breezes prevents, especially during the hot season, the discomforts and suffering of excessive heat which is usually associated with the wind in the lower latitudes of the North Temperate Zone" (Wall, *loc. cit.*).

The number of clear and fair days is about the same for each of the resorts under consideration, and the yearly average is large, equal to that of San Diego or of Santa Barbara. Three out of four days during the winter months are fair or clear. The average number of rainy days for the year is considerably higher than at Cannes, Nice, or San Remo; but, as before mentioned, the greater part of the rain comes in the summer. It is to be regretted that there are no meteorological data, so far as known to the writer, for points situated upon the elevated ridge in the interior. Such data would probably approximate more nearly to those of Jacksonville and Tampa, which are situated some miles from the coast, and the mean average daily range of these two places, as we have already observed, is considerably greater than in the case with the coast towns.

Of Winter Park, situated 133 miles south of Jacksonville, forty miles west of the Atlantic Ocean and

eighty miles east of the Gulf of Mexico, with an altitude of over one hundred feet, we are told that "the air is fine and dry, the country around being made up of high pine lands, that there are no marshes or stagnant ponds, but instead a chain of beautiful, clear-water lakes. The temperature of the winter days averages from 60° to 65° F. during the twenty-four hours. Occasionally there is a frost, and once in a while freezing temperature occurs at night, but none during the days. It rains very seldom during the winter months, but there are heavy dews night and morning." (Report on Health Resorts, Transactions of the American Climatological Association, 1895.)

The climate of Key West is "essentially tropical, and typically insular." As will be seen in the tables, July shows a much greater amount of precipitation than the winter months, and such is the case with the other summer months; there is practically a dry (winter) and a rainy (summer) season. From this fact, however, it must not be supposed that it rains most of the time in summer, for July, for instance, shows 25.5 clear and fair days, and the other summer months about the same proportion.

It will be also noticed that the temperature is remarkably equable, the mean of the warmest being 91.3°, and of the coldest 66.5° F.; the diurnal range is also very small. The city of Key West, the largest in the State next to Jacksonville (about 19,945 inhabitants), is situated upon a coral island of the same name, seven miles long and from one to two miles broad. There are no springs on the island, and the water supply is derived from rain water or from distillation.

The foliage and fruits are luxuriant and more or less tropical. The streets of the town are broad, the residences are shaded with tropical trees, palms and brilliant flowers grow in profusion, all giving the town a very picturesque appearance.

Key West is not known as a health resort, as are the other well-known resorts in Florida; it is said, however, to be healthy, and it at least possesses an ideal semi-tropical insular climate. Its sanitary condition is unknown to the writer. It is the most southern city of the United States. "The fishing and boating are unsurpassed, and there are a number of charming drives on the island" The Florida East Coast R. R. has its terminus at Key West from whence steamers run to Havana in a few hours.

The warmth, abundant sunshine, equable temperature, marine atmosphere, and all the varied charms of land and water will always render Florida one of the great winter resorts of the United States. It is easily accessible from the Northern States by rail or by boat, and it possesses an unrivalled system of hotels. As Dr. Wall truly says: "To the vast majority of the valetudinarian class from other causes than consumption, the winter's sojourn in the mild marine climate of Florida will always be found a powerful adjunct in reëstablishing the impaired health."

Finally, to the person who wants a *change* from the exhausting routine of city, social, or business life, and who, from such or other reasons, has become "stale," to speak in athletic parlance, Florida offers a veritable paradise, provided a simple outdoor life is pursued and business and society are abandoned. The writer can speak from personal experience of the keen delight one experiences in the trip up the St. John's or Ocklawaha River; fishing in the Gulf of Mexico or hunting for sea-beans on the shore. With such novel surroundings, mere existence is a pleasure, and the subtle influences of the balmy atmosphere bring renewed health and strength of mind and body.

EDWARD O. OTIS.

Fluidextracta.—Fluid extracts are liquid alcoholic preparations, made by percolation, of definite and uniform strength, being so prepared that 1 c.c. of the fluid extracts represents exactly one gram of the crude drug. Practically, they are tinctures of 100 per cent. strength. The advantages of the fluid extracts are: (1) concentration; (2) permanence; (3) definite strength. In the manufacture of fluid extracts four general processes are used: (1) percolation, with partial evaporation; (2) percolation with incomplete exhaustion; (3) repercolation; and (4) percolation and maceration.

There are eighty-five fluid extracts in the U. S. P., and for the medical practitioner probably the most convenient classification will be one based on similarity of dose.

Dose of one minim (0.05): Fluid extracts of aconite, belladonna root, cannabis indica, capsicum, digitalis, gelsemium, ipecac (as expectorant), nux vomica, scopola, staphisagria, and stramonium.

Dose of one and a half minims (0.1): Fluid extracts of phytolacca (as alterative), sanguinaria, squill, and veratrum.

Dose of three minims (0.2): Fluid extracts of colchicum seed, conium, hyoscyamus, and quillaja.

Dose of five minims (0.3): Fluid extract of savine.

Dose of eight minims (0.5): Fluid extracts of convallaria, euonymus, lobelia, lupulin, podophyllum, and quassia.

Dose of fifteen minims (1.0): Fluid extracts of apocynum, aromatic, bitter orange peel, calamus, cascara sagrada, cascara sagrada aromatic, chirata, cimicifuga, cinchona, cubeb, cypripedium, eriodictyon, frangula, gentian, geranium, ginger, krameria, leptandra, phytolacca (emetic), quercus, rhubarb, rhus glabra, rubus, scutellaria, senega, and serpentaria.

Dose of thirty minims (2.0): Fluid extracts of berberis, buchu, calumba, chimaphila, coca, ergot, eucalyptus, eupatorium, glycyrrhiza, grindelia, guarana, hamamelis leaves, hydrastis, lappa, pilocarpus, prunus virginiana, rose, sarsaparilla, sarsaparilla compound, senna, stillingia, sumbul, uva ursi, valerian, viburnum opulus, viburnum prunifolium and xanthoxylum.

Dose of one fluidram (4.0): Fluid extracts of matico and spigelia.

Dose of two fluidrams (8.0): Fluid extracts of taraxacum and triticum.

For external use; no dose given by U. S. P. Fluid extract of mezereum.

R. J. E. SCOTT.

Flukes.—*Trematoda.* A class of parasitic flatworms which includes those possessing a digestive tract. The adults of these Platyhelmia are found in all classes of vertebrates and the larvæ occur in several invertebrates, most often in snails. Flukes may occur in any of the organs but are most often found in the urinary bladder, lungs, intestine, or liver. See *Trematoda.*

A. S. P.

Fluorescein.—Resorcinolphthalein anhydride, $C_{20}H_{12}O_5$, is a yellowish-red crystalline powder, prepared by fusing together 5 parts of phthalic anhydride and 7 parts of resorcinol at a temperature of about 200° C. It is insoluble in pure water but dissolves in alkaline fluids. The solution employed at the Royal Ophthalmic Hospital in London is composed of fluorescein 2, and sodium bicarbonate 3, in water 100. It is used in the diagnosis of corneal ulceration and of the presence of foreign bodies in the cornea. The instillation of a few drops in the eye will color green any part of the cornea denuded of its epithelium while a foreign body will be surrounded by a green ring. The conjunctiva where abraded will assume a yellowish hue.

T. L. S.

Fœniculum.—FENNEL. The fruit of *Fœniculum Fœniculum* (L.) Karst. ("*F. capillaceum* Gilibert," U. S. P.—fam. *Umbelliferæ*).

From a perennial or biennial herb with a tall, smooth, green, branching stem and pinnate, skeleton-like leaves, the latter consisting of but little more than straggling, branching midribs and veins, arising from broad, concave, half-sheathing petioles. Umbels compound, naked, many-flowered.

Native of Southern Europe, Western and Southern Asia, etc.; it exists in several varieties, and has been long and extensively cultivated.

Of two separate or united carpels, each 0.5 to 1 centimeter (⅕ to ⅖ in.) long, about one-third as broad and one-sixth as thick, oblong or a little narrowed at the summit, more or less curved, bearing five very prominent and stout light-colored ribs upon the back, otherwise smooth, yellowish or brownish-green; pericarp containing an oil tube between each two ribs and two upon the flat side; odor pleasantly aromatic; taste sweet and pleasantly aromatic.

Sweet, or Roman fennel, with very large, long, light-colored, pale-greenish fruits, and a particularly pleasant odor and taste, from cultivated plants of southern Europe, is much the best. German, or Saxon, with shorter and proportionately thicker fruits, is cultivated in Germany. Wild, or bitter fennel, is from wild plants growing in the south of France.

Fennel contains about three and a half per cent. of an *essential oil* very much like that of anise, being composed of a large proportion of *anethol*, a smaller one of a hydrocarbon of the terpene series, etc.

Fennel is a mild aromatic of exactly the same medicinal qualities as anise. It is, however, less used in medicine than that, but is considerably consumed as a flavor in cordials, as a spice and in veterinary practice. It also enters, as a carminative, to prevent griping, into the compound infusion of senna, and its oil similarly into the compound spirit of juniper and the compound licorice powder. Both are often added to prescriptions. with this object. The dose of fennel is gr. viij.–xxx. (0.5–2.0).

Oleum Fœniculi, U. S. P., a volatile oil distilled from the above, is thus described in the Pharmacopœia:

A colorless or pale yellowish liquid, having the characteristic, aromatic odor of fennel, and a sweetish, mild, and spicy taste.

Specific gravity: 0.953 to 0.973 at 25° C. (77° F.).

Between 5° and 10° C. (41° and 50° F.) it usually solidifies to a crystalline mass, but occasionally it remains liquid at a considerably lower temperature.

Soluble in an equal volume of alcohol, the solution being neutral to litmus paper; also soluble in an equal volume of glacial acetic acid.

The oil is not colored by the addition of a drop of ferric chloride T. S. (absence of some foreign oils containing *phenols*, and of *carbolic acid*).

If the oil be dropped into water, without agitation, it should not produce a milky turbidity (absence of *alcohol*). It should contain about sixty per cent. of anethol. The relatively higher temperature at which crystals of this substance begin to separate indicates its percentage and of course determines its quality. Another substance present in it is *fenchene*, with pinene, phallandrene, etc. Its properties and uses are precisely like those of oil of anise, and the dose is ♏ i. to v. (0.06–0.3). The official water (*Aqua Fœniculi*), having a strength of one-fifth of one per cent., is usually employed as a vehicle, but is carminative in doses of fl ʒij.–viii. (8.0–30.0).

Henry H. Rusby.

Fœtus.—See *Fetus*.

Folliculitis Decalvans.—This disease has been described under many names, such as alopécies cicatricielles innominées (Besnier), folliculite épilante (Quinquaud), acné decalvante (Lailler), ulerythema sycosiforme (Unna), and Brocq would include under it Kaposi's dermatitis papillaris capillitii.

Symptoms.—It may affect the scalp alone, or the bearded portion of the face from which it may extend to the scalp, while the hair of the pubes and axilla do not escape at times. Upon the scalp it takes one of two forms:

1. The alopecia cicatrisata of Crocker, or *alopécie innominée* of Besnier or *pseudo pelade* of Brocq. In this form we find one or more irregular, ill-defined bald patches about which are tufts of hair. Sometimes it will be noted that just beyond the circumscribing tufts of hair are other small bald patches showing the extension of the disease into neighboring parts. The scalp

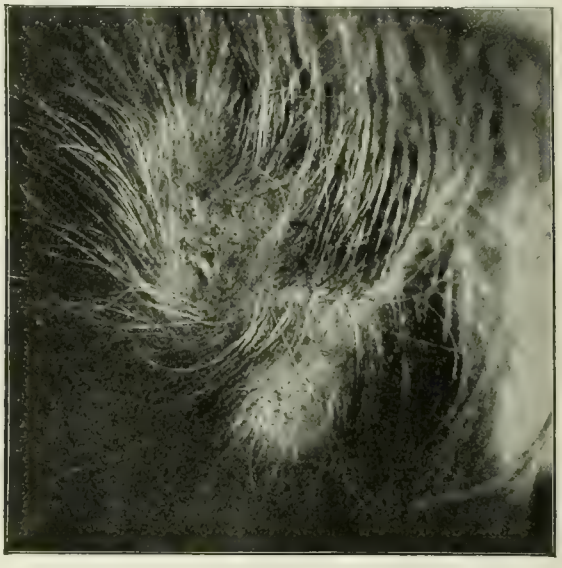


Fig. 2397.—Folliculitis Decalvans. Early stage. (Author's case.)

in the patches is cicatricial, thinned, slightly depressed, smooth or stippled over with follicular openings. Signs of active inflammation may be entirely wanting or confined to the mouths of the follicles. At other times there is a slight, diffused redness with furfuraceous desquamation; or there may be some very small and superficial pustules occupying the infundibula of the hair, which in a short time are transformed into depressions out of which the hair falls. As soon as the hair falls all signs of inflammation subside. The hair is permanently destroyed, and the scalp is gradually transformed into a mass of cicatricial tissue. New spots develop here and there in an erratic manner.

2. *Depilating Folliculitis.*—This is the *folliculite épilante* of Quinquaud, and the *acné decalvante* of Lailler. While the first form is confined to the scalp, the second may also affect the beard, pubes, and axilla. It differs from the first form in being accompanied by more marked inflammation. Like that it produces bald, smooth, irregularly shaped, cicatricial patches. These are scattered through the hair, and are of various sizes up to that of a silver quarter of a dollar. In them are some small red points, while about their edges and in their neighborhood are purulent points, miliary abscesses, and red papules, each with a hair in its center. The folliculitis causes destruction of the hair which is permanent, giving rise to the cicatricial appearance. If there are a number of patches near each other they will be separated by tufts of sound hair. If the disease occurs on other parts than the scalp it will give rise to similar appearances.

Folliculitis decalvans is a chronic and progressive process, and it is impossible to say how great its ravages will be. It is usually slow in its progress. Pruritus is often marked.

Etiology.—Nothing positive is known of the cause of alopecia cicatrisata. Some observers have found microorganisms in relation with depilating folliculitis. Brocq considers staphylococcus as the cause, and Quinquaud a micrococcus. Inasmuch as some of the cases yield to antisyphilitic treatment, it has been assumed that some of the cases are due to syphilis.

Diagnosis.—Occurring on the scalp, it must be diagnosed from alopecia areata, the baldness due to favus, and lupus erythematosus. From alopecia areata it is distinguished readily by the fact that it is cicatricial in character, while in alopecia areata the skin is unaltered.

Fig. 2398.—Folliculitis Decalvans. A more advanced stage of the disease. (Author's Case.)

Moreover, in the latter disease there are never signs of follicular inflammation. If there are favus crusts or evidences of folliculitis the diagnosis from favus is easy, as in folliculitis decalvans we do not have sulphur-yellow crusts, and in favus we do not have folliculitis. In inactive cases it is impossible to tell which disease we have, as both diseases produce baldness of the same general character. The history of the case will, however, enable us to decide. Lupus erythematosus presents a greater amount of redness and large adherent scales. Its patches are completely bald and have no tufts of sound hair in them. The bald patches resulting from injury or impetigo should cause no confusion. The former are usually linear, and the latter are of small size.

Treatment.—Thus far, treatment has not been of much avail. Quinquaud recommends washing the patches with soap and water, and painting the scalp in their vicinity with tincture of iodine. Every morning the patches are to be bathed with hydrarg. biniodidi, gr. i. (0.065); hydrarg. bichloridi, gr. iv. (0.26); alcohol, ℥ ss. (16); aquæ destillat. ad ℥ iv. (125). We have seen the disease apparently checked by the daily use of ac. salicylic, gr. xv., sulphur. colloidal, ℥ j.; eucerin and adepis anserini, ad ℥ j.; ol. rosae geran. gr. x., well rubbed into the patches. The Kromayer ultraviolet lamp has benefited some cases. *X*-rays, by the single dose method, might be tried. Of course the baldness is permanent, the scalp being converted into a cicatrix.

George T. Jackson.

Fomentations are liquids which are applied to the surface of the body by means of flannel or some other absorbent material. They are usually applied hot, and are employed for the relief of pain, and for the conditions for which poultices are indicated. The flannel or other material which is used is called a *stupe;* but the two terms *fomentation* and *stupe* are often used indiscriminately. Fomentations only retain the heat for a short time, and so need frequent renewal. They are but little used now.

R. J. E. Scott.

Fomites.—See *Disinfection:*

Fontana, Felice.—This celebrated scientist, naturalist, and physician was born at Pomaroli, in the Tyrol, April 15, 1730. While a lad he was sent to Italy, where he spent the remainder of his life. He early evinced a love for study, especially in the natural sciences. He was educated in the Universities of Verona, Bologna, and Padua, later distinguishing himself in scientific studies at Florence and Rome. He was appointed professor of rational philosophy by Francis I, at the University of Pisa, then the most celebrated school of the time, and later was made director of the Museum of Physical and Natural History at Florence, which position he held for the following thirty years of his life. He died March 9, 1805.

Fontana is most widely recognized through his work as an anatomist. While director of the Museum at Florence he had made a collection of twenty-four figures, representing the human body, which were developed in colored wax and arranged in groups demonstrating various parts of the body, such as muscles, nerves, intestines, etc. To him was accredited much of the necessary dissection in the development of these figures. He did extensive anatomical work on the eye, and discovered the space in the pectinate ligament of the iris, which bears his name, Fontana's spaces. Fontana's mark, a transverse fold seen in a cut nerve trunk, was a discovery of his. The canal of Schlemm also bears his name. He contributed freely to medical literature, but did not confine himself in his writings to anatomical subjects.

Among the most important of his works are: "Descrizione e usi di alcuni stromenti per misurare la salubrità dell' aria"; "Trattato del Veleno della vipera," etc.; "Varie sperienze sulla riproduzione de' nervi"; "Descrizione d'un nuovo canale dell' occhio."

E. L. J.

Food and Drug Control Laws.—In this article will be discussed the object of the laws, their practical application and the general principles of food and drug inspection.

History of Food Adulteration.—The preacher in the book of Ecclesiastes gave abundant proof that he was a seer of no mean ability when he gave expression to the following: "And there is no new thing under the sun; is there anything whereof it may be said, see, this is new? It hath been already of old time which was before us." This truism applies not only to religious thought and philosophy, but in a broad sense to almost every phase of human activity. To those who have had no occasion to make a study of the question, it is generally supposed that food and drug adulteration is of rather modern date, and that the passage of the laws prohibiting such adulteration is of very recent years. This is not the case, for we find by again referring to the inspired book that the prophet Amos, many hundred years before the Christian era, uttered a solemn warning to the children of Israel to cease their adulteration of wheat and to refrain from falsifying their balances and measures, as the following from Amos viii: 4, 5, 6 will show: "Hear this, O ye that swallow up the needy, even to make the poor of the land to fail, saying, when will the new moon be gone, that we may sell corn? And the

Sabbath that we may set forth wheat, making the ephah small and the shekel great, and falsifying the balances by deceit? That we may buy the poor for silver, and the needy for a pair of shoes; yea, and *sell the refuse of the wheat?*"

It seems quite apparent, therefore, that from the very earliest history of the race whenever primeval man raised more of any one commodity than was necessary to support himself and family and the idea of exchange of commodities and of buying and selling therefore arose, his innate selfishness and greed prompted him to defraud and cheat his neighbor and, in the case of food and food products, to practise such deceptions by methods which we now define as "adulteration." The great and wise Solomon declared: "A false balance is an abomination to the Lord, but a just weight is his delight."

A survey of Greek and Roman history discloses the fact that bakers and wine merchants became so fraudulent in their dealings with the trade and so brazenly open in their adulteration of bread and wine that several hundred years before Christ, stringent laws were passed prohibiting the adulteration of bread and wine under penalty of the most severe punishment.

In the fourteenth century, England passed laws to prevent the adulteration of bread and wine and also meat products. We read that in 1387 several London bakers were discovered who had made holes in their molding boards, and thus they retained for their own uses the amount of dough these holes would hold from the amount of dough brought to them by their customers to be baked. The Lord Mayor had these thieving bakers placed in the pillory for six hours with the stolen dough tied about their necks. On another occasion, a butcher was discovered who had washed some decomposed meat with a solution of saltpeter so that it might be sold without detection of its pollution. He was tied to the stake and the spoiled meat was burned under his nose. It appears that in these early days, the punishment was made to somewhat suit the nature of the crime.

In 1392, a London saleswoman thickened the bottom of the quart measure she used with a heavy layer of pitch so as to give short measure. The records recite the fact that she was tied up in the public square and the quart measure, cut in halves, was hung about her neck so that the public might see the nature of her crime.

We find, also, that Germany very early passed laws to prevent adulteration, and a certain grim humor seems to be connected with the punishment meted out to adulterators those days in Germany as well as in England. The court records in Mayence, Germany, recite the fact that in 1428 one Theobald Werner, was found guilty of selling grossly adulterated wine; he was sentenced to a fine in cash, his entire supply of wine, with the exception of one gallon, was confiscated and emptied into the Rhine, and he was sentenced to drink at one sitting in the Court House the one gallon that was retained. The historian adds the curious comment, that "Werner died quietly two hours after drinking the gallon."

Thus, we see that the criminal practice of food adulteration is not a modern crime, nor is the enactment of food and drug laws a modern invention, although, like many of the arts and sciences, these laws seem to have been lost during the march of the centuries, to be re-discovered or re-enacted when modern conditions had become intolerable.

The first food laws enacted in this country were those enacted in the States of New York and New Jersey in 1881 and in Massachusetts in 1882. The passage of these laws seemed to be the result of a general awakening and a wide-spread interest in the subject of food adulteration following the passage of the English Adulteration Act of 1875. In October, 1880, the report of a committee consisting of Dr. John S. Billings, U. S. A., Chancellor Williamson of New York, A. H. Hardy of Boston, and Charles F. Chandler of New York, framed a law which was submitted to the legislatures of several States with the above-mentioned result. This model law, or a law similar thereto, was later enacted in the states of Connecticut, California, Indiana, Illinois, Kansas, Kentucky, Michigan, Mississippi, North Carolina, Oregon, Ohio, Pennsylvania, Tennessee, and Wisconsin. It should be noted, however, that in none of these latter States was there an organization created or funds appropriated to make the law effective at the time of passage.

The present national food and drug act, passed June 30, 1906, was preceded by some seventeen or eighteen years of constant agitation, by the analyses of foods and drugs and publication of the results of such analyses by the Bureau of Chemistry of the U. S. Department of Agriculture, and by excellent work done along the same line by the State of Massachusetts; in almost every session of congress for seventeen years preceding the final date of enactment, bills were presented calculated to control interstate traffic in adulterated or misbranded foods and drugs, but owing to the interest of certain powerful manufacturers such legislation was defeated. It was only after years of education that the demand of the people became so strong and insistent that, finally, on the closing day of the Fifty-ninth Congress of 1906, the bill was passed and became a law.

Since the passage of the national act, food and drug control laws have been enacted and are in more or less successful operation in every State in the Union except in West Virginia and New Mexico. These laws, in a general way, conform more or less closely to the provisions of the national act. West Virginia has had a food law for several years past, but up to the present time (1913), the legislature has failed to make appropriation by which the act may be made effective.

The National Food and Drugs Act.—The national food and drugs act was amended in 1913 by what are known as the Gould and Sherley amendments. The amended food and drugs act is herewith given as it is now on the Federal statute book:

THE FOOD AND DRUGS ACT, JUNE 30, 1906.

An act for preventing the manufacture, sale, or transportation of adulterated or misbranded or poisonous or deleterious foods, drugs, medicines, and liquors, and for the regulating of traffic therein, and for other purposes.

BE IT ANACTED BY THE SENATE AND HOUSE OF REPRESENTATIVES OF THE UNITED STATES OF AMERICA IN CONGRESS ASSEMBLED, That it shall be unlawful for any person to manufacture within any Territory or the District of Columbia any article of food or drug which is adulterated or misbranded, within the meaning of this Act; and any person who shall violate any of the provisions of this section shall be guilty of a misdemeanor, and for each offense shall, upon conviction thereof, be fined not to exceed five hundred dollars or shall be sentenced to one year's imprisonment, or both such fine and imprisonment, in the discretion of the court, and for each subsequent offense and conviction thereof shall be fined not less than one thousand dollars or sentenced to one year's imprisonment, or both such fine and imprisonment, in the discretion of the court.

Sec. 2. That the introduction into any State or Territory or the District of Columbia from any other State or Territory or the District of Columbia, or from any foreign country, or shipment to any foreign country of any article of food or drug which is adulterated or misbranded, within the meaning of this Act, is hereby prohibited; and any person who shall ship or deliver for shipment from any State or Territory or the District of Columbia, or to a foreign country, or who shall receive in any State or Territory or the District of Columbia from any other State of Territory or the District of Columbia, or foreign country, and having so received, shall deliver, in original unbroken packages, for pay or otherwise, or offer to any other person, any such article so adulterated or misbranded within the meaning of this Act, or any person who shall sell or offer for sale in the District of Columbia or the Territories of the United States any such adulterated or misbranded foods or drugs, or export or offer to export the same

to any foreign country, shall be guilty of a misdemeanor, and for such offense be fined not exceeding two hundred dollars for the first offense, and upon conviction for each subsequent offense not exceeding three hundred dollars or be imprisoned not exceeding one year, or both, in the discretion of the court: *Provided*, That no article shall be deemed misbranded or adulterated within the provisions of this Act when intended for export to any foreign country and prepared or packed according to the specifications or directions of the foreign purchaser when no substance is used in the preparation or packing thereof in conflict with the laws of the foreign country to which said article is intended to be shipped; but if said article shall be in fact sold or offered for sale for domestic use or consumption, then this proviso shall not exempt said article from the operation of any of the other provisions of this Act.

Sec. 3. That the Secretary of the Treasury, the Secretary of Agriculture, and the Secretary of Commerce and Labor shall make uniform rules and regulations for carrying out the provisions of this Act, including the collection and examination of specimens of foods and drugs manufactured, or offered for sale in the District of Columbia, or in any territory of the United States, or which shall be offered for sale in unbroken packages in any state other than that in which they shall have been respectively manufactured or produced, or which shall be received from any foreign country, or intended for shipment to any foreign country, or which may be submitted for examination by the chief health, food, or drug officer of any State, Territory or the District of Columbia, or at any domestic or foreign port through which such product is offered for interstate commerce, or for export or import between United States and any foreign port or country.

Sec. 4. That the examination of specimens of foods and drugs shall be made in the Bureau of Chemistry of the Department of Agriculture, or under the direction and supervision of such Bureau, for the purpose of determining from such examinations whether such articles are adulterated or misbranded within the meaning of this Act; and if it shall appear from any such examination that any of such specimens is adulterated or misbranded within the meaning of this Act, the Secretary of Agriculture shall cause notice thereof to be given to the party from whom such sample was obtained. Any party so notified shall be given an opportunity to be heard, under such rules and regulations as may be prescribed as aforesaid, and if it appears that any of the provisions of this act have been violated by such party, then the Secretary of Agriculture shall at once certify the facts to the proper United States District Attorney, with a copy of the results of the analysis or the examination of such article duly authenticated by the analyst or officer making such examination, under the oath of such officer. After judgment of the court, notice shall be given by publication in such manner as may be prescribed by the rules and regulations aforesaid.

Sec. 5. That it shall be the duty of each district attorney to whom the Secretary of Agriculture shall report any violation of this Act, or to whom any health or food or drug officer or Agent of any State, Territory or the District of Columbia shall present satisfactory evidence of any such violation, to cause appropriate proceedings to be commenced and prosecuted in the proper courts of the United States, without delay, for the enforcement of the penalties as in such case herein provided.

Sec. 6. That the term "drug," as used in this Act, shall include all medicines and preparations recognized in the United States Pharmacopœia or National Formulary for internal or external use, and any substance or mixture of substances intended to be used for the cure, mitigation or prevention of disease of either man or other animals. The term "food," as used herein, shall include all articles used for food, drink, confectionery, or condiment by man or other animals, whether simple, mixed or compound.

Sec. 7. That for the purpose of this Act an article shall be deemed to be adulterated: In case of drugs.

First, If, when a drug is sold under or by a name recognized in the United States Pharmacopœia or National Formulary, it differs from the standard of strength, quality, or purity, as determined by the test laid down in the United States Pharmacopœia or National Formulary official at the time of investigation: *Provided*, That no drug defined in the United States Pharmacopœia or National Formulary shall be deemed to be adulterated under this provision if the standard of strength, quality, or purity be plainly stated upon the bottle, box, or other container thereof although the standard may differ from that determined by the test laid down in the United States Pharmacopœia or National Formulary.

Second. If its strength or purity shall fall below the professed standard or quality under which it is sold.

In the case of confectionery:

If it contain terra alba, barytes, talc, chrome yellow, or other mineral substance or poisonous color or flavor, or other ingredient deleterious or detrimental to health, or any vinous, malt, or spirituous liquor or compound or narcotic drug.

In the case of food:

First. If any substance has been mixed and packed with it so as to reduce or lower or injuriously affect its quality or strength.

Second. If any substance has been substituted wholly or in part for the article.

Third. If any valuable constituent of the article has been wholly or in part abstracted.

Fourth. If it be mixed, colored, powdered, coated or stained in a manner whereby damage or inferiority is concealed.

Fifth. If it contain any added poisonous or other added deleterious ingredient which may render such article injurious to health: *Provided*, That when in the preparation of food products for shipment they are preserved by any external application applied in such manner that the preservative is necessarily removed mechanically, or by maceration in water, or otherwise, and directions for the removal of said preservative shall be printed on the covering or the package, the provisions of this Act shall be construed as applying only when said products are ready for consumption.

Sixth. If it consist in whole or in part of a filthy, decomposed, or putrid animal or vegetable substance, or any portion of an animal unfit for food, whether manufactured or not, or if it is the product of a diseased animal, or one that has died otherwise than by slaughter.

Sec. 8. That the term "misbranded," as used herein, shall apply to all drugs, or articles of food, or articles which enter into the composition of food, the package or label of which shall bear any statement, design, or device regarding such article, or the ingredients or substances contained therein which shall be false or misleading in any particular, and to any food or drug product which is falsely branded as to the State, Territory, or country in which it is manufactured or produced.

That for the purpose of this Act an article shall also be deemed to be misbranded:

In case of drugs:

First. If it be an imitation of or offered for sale under the name of another article.

Second. If the contents of the package as originally put up shall have been removed, in whole or in part, and other contents shall have been placed in such package, or if the package fail to bear a statement on the label of the quantity or proportion of any alcohol, morphin, opium, cocain, heroin, alpha, beta eucain, chloroform, cannabis indica, chloral, hydrate, or acetanilid, or any derivative or preparation of any such substances contained therein.

Third. If its package or label shall bear or contain any statement, design, or device regarding the curative or therapeutic effect of such article or any of the ingredients or substances contained therein which is false and fraudulent.

In the case of food:

First. If it be an imitation of or offered for sale under the distinctive name of another article.

Second. If it be labeled or branded so as to deceive or mislead the purchaser, or purport to be a foreign product when not so, or if the contents of the package as originally put up shall have been removed in whole or in part and other contents shall have been placed in such package, or if it fail to bear a statement on the label of the quantity or proportion of any morphin, opium, cocain, heroin, alpha or beta eucain, chloroform, cannabis indica, chloral hydrate, or acetanilid, or any derivative or preparation of any such substances contained therein.

Third. If in package form the quantity of the contents be not plainly and conspicuously marked on the outside of the package in terms of net weight, measure or numerical count. *Provided*, however that reasonable variation shall be permitted and tolerance and also exemptions as to small packages shall be established by rules and regulations made in accordance with Section 3 of this Act.

Fourth. If the package containing it or its label shall bear any statement, design, or device regarding the ingredients or the substances contained therein, which statement, design, or device shall be false or misleading in any particular: *Provided*, That an article of food which does not contain any added poisonous or deleterious ingredients shall not be deemed to be adulterated or misbranded in the following cases:

First. In the case of mixtures or compounds which may be now or from time to time hereafter known as articles of food, under their own distinctive names, and not an imitation of or offered for sale under the distinctive name of another article, if the name be accompanied on the same label or brand with a statement of the place where said article has been manufactured or produced.

Second. In the case of articles labeled, branded, or tagged so as to plainly indicate that they are compounds, imitations, or blends, and the word "compound," "imitation," or "blend," as the case may be, is plainly stated on the package in which it is offered for sale; *Provided*, That the term blend as used herein shall be construed to mean a mixture of like substances, not including harmless coloring or flavoring ingredients used for the purpose of coloring and flavoring only: *And provided further*, That nothing in this Act shall be construed as requiring or compelling proprietors or manufacturers of proprietary foods which contain no unwholesome added ingredient to disclose their trade formulas, except in so far as the provisions of this Act may require to secure freedom from adulteration or misbranding.

Sec. 9. That no dealer shall be prosecuted under the provisions of this Act when he can establish a guarantee signed by the wholesaler, jobber, manufacturer, or other party residing in the United States, from whom he purchases such articles, to the effect that the same is not adulterated or misbranded within the meaning of this act, designating it. Said guaranty, to afford protection, shall contain the name and address of the party or parties making the sale of such articles to such dealer, and in such case said party or parties shall be amenable to the prosecutions, fines and other penalties which would attach, in due course, to the dealer under the provisions of this Act.

Sec. 10. That any article of food, drug or liquor that is adulterated or misbranded within the meaning of this Act, and is being transported from one State, Territory, District, or insular possession to another for sale, or, having been transported, remains unloaded, unsold, or in original unbroken packages, or if it be sold or offered for sale in the District of Columbia or the Territories, or insular possessions of the United States, or if it be imported from a foreign country for sale, or if it is intended for export to a foreign country, shall be liable to be proceeded against in any district court of the United States within the district where the same is found, and seized for confiscation by a process of libel for condemnation. And if such article is condemned as being adulterated or misbranded, or of a poisonous or deleterious character, within the meaning of this Act, the same shall be disposed of by destruction or sale, as the said court may direct, and the proceeds thereof, if sold, less the legal costs and charges, shall be paid into the Treasury of the United States, but such goods shall not be sold in any jurisdiction contrary to the provisions of this Act or the laws of that jurisdiction: *Provided, however,* That upon the payment of the costs of such libel proceedings and the execution and delivery of a good and sufficient bond to the effect that such articles shall not be sold or otherwise disposed of contrary to the provisions of this Act, or the laws of any State, Territory, District, or insular possession, the court may by order direct that such articles be delivered to the owner thereof. The proceedings of such libel cases shall conform, as near as may be, to the proceedings in admiralty, except that either party may demand trial by jury of any issue of fact joined in any such case, and all such proceedings shall be at the suit of and in the name of the United States.

Sec. 11. The Secretary of the Treasury shall deliver to the Secretary of Agriculture, upon his request from time to time, samples of foods and drugs which are being imported into the United States or offered for import, giving notice thereof to the owner or consignee, who may appear before the Secretary of Agriculture, and have the right to introduce testimony, and if it appear from the examination of such samples that any article of food or drug offered to be imported into the United States is adulterated or misbranded within the meaning of this Act, or is otherwise dangerous to the health of the people of the United States, or is of a kind forbidden entry into, or forbidden to be sold or restricted in sale in the country in which it is made or from which it is exported, or is otherwise falsely labeled in any respect, the said article shall be refused admission, and the Secretary of the Treasury shall refuse delivery to the consignee and shall cause the construction of any goods refused delivery which shall not be exported by the consignee within three months from the date of notice of such refusal under such regulations as the Secretary of the Treasury may prescribe: *Provided,* That the Secretary of the Treasury may deliver to the consignee such goods pending examination and decision in the matter on execution of a penal bond for the amount of the full invoice value of such goods, together with such duty thereon, and on refusal to return such goods for any cause to the custody of the Secretary of the Treasury, when demanded, for the purpose of excluding them from the country, or for any other purpose, said consignee shall forfeit the full amount of the bond: *And Provided Further,* That all charges for storage, cartage, and labor on goods which are refused admission or delivery shall be paid by the owner or consignee, and in default of such payment shall constitute a lien against any future importation made by such owner or consignee.

Sec. 12. That the term "Territory" as used in this Act shall include the insular possessions of the United States. The word "person" as used in this Act shall be construed to import both the plural and the singular, as the case demands, and shall include corporations, companies, societies and associations. When construing and enforcing the provisions of this Act, the act, omission, or failure of any officer, agent, or other person acting for or employed by any corporation, company, society, or association, within the scope of his employment or office, shall in every case be also deemed to be the act, omission, or failure of such corporation, company, society, or association as well as that of the person.

Sec. 13. That this Act shall be in force and effect from and after the first day of January, nineteen hundred and seven.

Approved June 30, 1906.

Rules and Regulations.—It should be noted that Section 3 of the Act provides that the Secretary of the Treasury, the Secretary of Agriculture, and the Secretary of Commerce and Labor are authorized and empowered to make uniform rules and regulations for carrying out the provisions of the act. Accordingly, rules and regulations were adopted, which have become more or less models for the various States in carrying out the provisions of the respective State food and drug acts. It is seen, therefore, that a general movement toward uniformity of food and drug control laws has been started, and this movement has been accelerated and intensified the past few years by the Committee on Cooperation, appointed by the Association of American Dairy, Food, and Drug Control officials, whose duty it is to bring about uniformity of laws, rules, and regulations, as well as to establish an effective plan of cooperation between the States and the federal government, and between the States themselves, in the enforcement of the national food and drug act and the various State food and drug laws.

Adulteration of Foods Defined.—The object of food and drug control laws is to prevent adulteration and misbranding. Section 7 of the act defines adulteration as applied to foods as follows: "First, if any substance has been mixed and packed with it so as to reduce or lower, or injuriously affect its quality or strength." An illustration of such adulteration is that of the use of inert condimental materials, such as hulls, grains, or olive pits added to ground spices, or the addition of water to milk. Previous to the passage of the national act and the effective enforcement of the various State laws, it would seem from the result of a large number of analyses of spices upon the market that most of the ground spices were thus adulterated. It was found, also, that not only milk was freely watered, but that little regard was given to the character and quality of the water that was added. Oysters were adulterated by the addition of ice for refrigeration purposes, the ice melting and thereby adding the resultant water to the oysters, to be sold as "oyster liquor." Ground coffees were largely adulterated with chicory, and teas with leaves of plants that did not belong to the tea family.

Adulteration is also defined, "Second, if any substance has been substituted, wholly or in part for the article." An example of this kind of adulteration in foods, which formerly was quite universally practised, was that of substituting cane sugar syrup for maple syrup, retaining only enough of the maple syrup to impart the maple flavor to the finished product, or by adding an artificial flavor made from the juice of the walnut tree, or extracted from corn-cobs.

Another definition is, "Third, if any valuable constituent of the article has been wholly or in part abstracted." An illustration of this form of adulteration is that of the abstraction of the volatile principle or oils of spices, such as the partial abstraction of the oil of cloves, or the use of abstracted tea leaves, which were dried and sold as tea, or the skimming of cream from milk in whole or in part. This form of adulteration seemed to be widespread.

Adulteration is further defined as, "Fourth, if it is mixed, colored, powdered, coated, or stained in a manner whereby damage or inferiority is concealed." This form of adulteration was practised on many articles of food, such as the coating of inferior grades of coffee whereby the damaged or worthless grains were made to appear of the same color as the valuable grains. Nuts were, also, coated and polished in order that spoiled or windfall nuts might not be detected. Damaged grains were mixed with grains of superior grade in just such quantities as to pass inspection. Canned fruits or vegetables were often times colored to make them appear better than they really were and to cover inferiority; relishes and pickles were highly colored for the same purpose, and an infinite number of otherwise wholesome articles were thus basely adulterated with inferior and often-

with unwholesome articles of food, the presence of which was concealed by various forms of manipulation, as laid down in this form of adulteration.

Another definition of adulteration is, "Fifth, if it contains any added poisonous or other added deleterious ingredient which may render such article injurious to health." I think it may, in all fairness, be said that it rarely happened that poisonous substances were premeditatedly added to food products by manufacturers who knew or believed such things to be poisonous. A certain class of preservatives that have been added to food products for the purpose of preserving or of hiding damage or inferiority, have been determined, upon investigation, to be capable of injuring the health if taken continuously in quantities used in the food products. Generally speaking, however, there are few illustrations in which this form of wilful adulteration might be said to exist.

The sixth definition for adulteration is, "Sixth, if it consist in whole or in part of a filthy, decomposed or putrid animal or vegetable substance, or any portion of an animal unfit for food, whether manufactured or not, or if it is the product of a diseased animal or one that has died otherwise than by slaughter."

Decomposition Defined.—An illustration of this form of definition is the sale of diseased animals for food purposes, or of perishable food products that have become unfit for use, such as decayed fruit or rotten eggs, or so-called "swelled" canned goods.

These definitions seem to be sufficiently definite for the purpose of effective enforcement of the act, with the single exception of the last one. The question of what constitutes decomposition, within the meaning of the act, is one upon which neither the manufacturers, the food officials, nor the scientists have as yet been able fully to agree. Scientifically, decomposition is constantly going on in all organized life, but at the same time, the process of repair is likewise simultaneously proceeding. When life ceases, the process of decomposition is ordinarily hastened without the possibility of repair, and thus, scientists declare that decomposition is everywhere present in organized tissue, in both the animal and vegetable kingdoms. It is quite evident that Congress did not have in mind technical decomposition in framing the law and the question naturally arises—what, then, is decomposition within the meaning of the act? It would seem at this time, from the consensus of opinion of the best authorities, that the proper definition for decomposition should be that of "unwholesomeness." That is to say, that foods or food products should be sufficiently fresh to be neither repulsive, disgusting, nor unhealthful to the consumer. It seems altogether probable that a repulsive or disgusting article of food, either by offensive odor or taste, might be unhealthful, although it might not actually produce disease. Repulsiveness and disgustingness are conditions such as involve an instinctive rejection of food, and would, unquestionably, interfere with normal alimentation or digestion.

Wholesomeness, therefore, includes the term "healthfulness," but is a stronger and broader definition to apply to foods. This term has the advantage which the words "unhealthfulness" or "decomposition" do not possess. Moreover, it seems to come closer to the popular meaning of what is a proper or an improper food. The unwholesome standard, then, for the term "decomposition," while acceptable to the public, would be infinitely easier of application in food control, as the means of the special senses, together with the application of common sense, would be brought to apply rather than the more or less doubtful bacterial or chemical standard which has been suggested, but which should be used only as a presumptive or confirmatory test. The impossibility of applying a bacterial standard to measure decomposition might be suggested by the fact that cultures from a fresh cut of meat, such as is ordinarily received from the hands of a retail butcher, gives large colonies of various forms of microorganisms, even those which are found in advanced stages of decomposition. This rule applies to every food product handled in the ordinary routine of supplying the daily needs of the consuming public.

It has been definitely proven that freshly laid eggs may contain bacteria, and often eggs but a few days old, while seeming to be perfectly fresh so far as taste, odor, or natural consistency of the yolk and white are concerned, are found to be very high in bacteria, even to the extent of large numbers of the colon bacillus group being present. It cannot be said that such eggs are decomposed and unfit for food, within the meaning of the law. The difficulties encountered in determining the question of unwholesome decomposition has made some dealers bold in placing upon the market food products in which a rather advanced or unwholesome stage of decomposition has taken place, but which have been sterilized in order to kill bacterial growth and, therefore, to prevent further decomposition; or preservatives have been added in such quantities as to inhibit further bacterial growth.

Food and drug control officials and laboratory workers are keenly aware of the fact that much scientific work must yet be done before a just and equitable standard for decomposition can be brought about for universal adoption. Producers, as well as consumers, are becoming more and more alive to the importance of an abundant food supply during these days of the so-called "high cost of living." It is, therefore, increasingly important that foods that are entirely wholesome should be conserved and sold for precisely what they are without any effort at concealing inferiority.

Adulteration of Drugs Defined.—The national act provides that drugs shall be deemed to be adulterated: "First, if when a drug is sold under or by a name recognized in the United States Pharmacopœia or National Formulary, it differs from the standard of strength, quality or purity, as determined by the test laid down in the United States Pharmacopœia or National Formulary official at the time of investigation; provided, that no drug defined in the United States Pharmacopœia or National Formulary, shall be deemed to be adulterated under this provision, if the standard of strength, quality or purity be plainly stated upon the bottle, box or other container thereof, although the standard may differ from that determined by the test laid down in the United States Pharmacopœia or National Formulary."

It seems to be quite evident, on the face of this definition, that it was a compromise measure, and it is believed that this definition of the adulteration of drugs is the weakest point in the law effecting real drug control. It is a most anomalous condition which, presumably is intended to control the adulteration of drugs, in that definite standards of quality, strength, and purity should be maintained, while the proviso contained in the law makes it possible for drugs that do not conform to such standards to be sold in interstate commerce, provided only that a statement of the deviation from such standards of strength, quality, and purity be, plainly stated upon the label. A law that presumes to standardize an article to be sold under an official name, but which permits another drug which does not comply with that official standard to be sold under the same name, is not only confusing in the extreme, but calculated to mislead and deceive the purchaser. Moreover, most of the official preparations are sold by retail druggists in broken packages or dispensed on physicians' prescriptions. In neither instance is the ultimate purchaser advised of the variation in standard from that stated on the label of the original package where substandard drugs are used in retailing or dispensing. Thus, the principal object of the law is defeated, and what is tremendously more important, the dispensing

physician is made to rely for therapeutic effect upon preparations of the substandard qualities of which he is unaware and therefore the desired physiological effects of such medicines are not produced.

Moreover, the determination of strength, quality, and purity as laid down in this definition is required to be made "by the test laid down in the United States Pharmacopœia or National Formulary," but for many of these official preparations no tests are given in these official documents, and hence drug control officials are confronted with their inability to comply with what seems to be the legal procedure necessary for determining such strength, quality, or purity.

The Association of American Dairy, Food, and Drug Control Officials at its last meeting (1913) appointed a committee to memorialize the President and Congress for a repeal of the proviso permitting the sale of substandard official drugs and medicinal preparations. It must be quite evident that real drug control will never be brought about until definite and certain standards are fixed and definitions and tests are so clearly stated as to leave no doubt of the legal procedure necessary to determine the strength, quality, and purity of such drugs.

Another definition of the adulteration of a drug is, "Second, if its strength or purity shall fall below the prescribed standard or quality under which it is sold." All drugs and medicinal preparations that do not come under the preceding clause of official drugs and medicinal preparations are classed under this second definition. This includes not only non-official drugs and medicinal preparations, but so-called "proprietary" and "patent" medicines.

The Kansas State Board of Health has adopted a rule for standardizing proprietary medicines which seems to be a simple but effective method of control. The regulation reads as follows: "Proprietary, medicinal preparations and similar medicinal products are required to conform in composition to the freshly prepared, non-deteriorated article, and to conform to the claims made for the preparation as to therapeutic properties, quality and strength." This regulation recognizes the fact that proprietary medicinal substances deteriorate, as well as the official products, and also recognizes that the standard of therapeutic efficiency to which every product is held is that claimed for the preparation by the manufacturer thereof.

Cosmetic and Toilet Articles.—Cosmetic and other toilet preparations making no claims to therapeutic effect, or when recommended for no bodily disease or ailment, are not considered to come within the scope of food and drug law control.

Included in the definition of adulteration for foods and drugs, comes the large class of beverages, including alcoholic liquors, medicinal waters, and so-called "soft drinks." Those articles that are used entirely or exclusively as beverages or drinks are classed as "foods"; those that are used or recommended for the cure or mitigation of disease, either in man or animal, are classed as "drugs."

Confectionery.—Confectionery is treated in a separate paragraph, apparently being classed as neither food nor drug. The definition of adulteration in the case of confectionery is: "If it contain terra alba, barytes, talc, chrome yellow, or other mineral substance, or poisonous color or flavor, or other ingredient deleterious or detrimental to health, or any vinous, malt, or spiritous liquor, or compound or narcotic drug."

Formerly, cheap candies contained considerable quantities of mineral substances in the shape of white earth, talc, etc. Conditions as to the quality or kind of material used in the manufacture of confectionery have been greatly improved since the passage of the national and State food and drug laws, although there is yet much to be accomplished in the matter of sanitation and healthfulness of employes handling such products.

Misbranding Defined.—Section 8 of the national act deals with the question of misbranding, and declares that an article of food or drug shall be deemed to be misbranded, "The package or label of which shall bear any statement, design, or device regarding such article, or the ingredients or substances contained therein which shall be false or misleading in any particular, and to any food or drug product which is falsely branded as to the State, Territory, or country in which it is manufactured or produced."

Probably the greatest fraud has been perpetrated in the sale of foods and drugs through representations upon the label or package which were entirely false or misleading, either by statement, design, or device. An illustration of misbranding under this section of the law, and one which was quite common before the enactment of the law, was the label upon so-called maple syrup, which was not composed of maple, and oftentimes was not composed even in part of maple syrup, although labeled as such and bearing the picture of a maple grove to further mislead the purchaser. The same thing was true of flavoring extracts, which bore the pictures of luscious fruits although made entirely from synthetic flavors, artificially colored. Many food and drug products also bore the name of some foreign country, leading the purchaser to believe that the article was imported and, therefore, of superior quality.

Misbranding of Drugs.—In the case of drugs, misbranding is further defined, "First, if it be an imitation of, or offered for sale under the name of another article."

This definition strikes at once to the all too prevalent practice of substitution, of which so many druggists are guilty. "Just as good" is rarely good, and never just, although the practice of substitution has been prevalent for so many years, often among pharmacists who in other respects conduct a most legitimate business. Substitution in any particular without due notice to the purchaser is thus construed to be misbranding.

Misbranding of products is further defined, "Second, if the contents of the package as originally put up shall have been removed in whole or part, and other contents shall have been placed in such package, or if the package fail to bear a statement on the label of the quantity or proportion of any alcohol, morphine, opium, cocaine, heroine, alpha or beta eucain, chloroform, cannabis indica, chloral hydrate, or acetanilid, or any derivative or preparation of any such substances contained therein," and "Third, if its package or label shall bear or contain any statement, design, or device regarding the curative or therapeutic effect of such article or any of the ingredients or substances contained therein which is false and fraudulent." (Sherley Amendment.)

It is the evident intent of the law to prevent or, at least, to curtail the use of habit-forming drugs, in that due notice is to be printed upon the label of all preparations containing so-called habit-forming drugs. In practical experience, it has been found that, in some instances at least, the statement of the habit-producing drugs simply lends to the further continuance of such habit by people who are already addicted to their use, as they are enabled to purchase proprietary medicines containing the drug to which they are addicted and thus defeat the various State laws requiring that such drugs be sold only upon a physician's prescription. A considerable number of such cases are on record and have been well authenticated.

Probably the greatest fraud has been practised in the sale of imitation articles. For illustration, so-called "medicinal waters" which have been artificially made, charged with carbon dioxide gas and sold as genuine mineral springs water.

In the effort of the government and the States to

prevent false and misleading statements as to the therapeutic value of so-called patent medicines, they found progress was stopped in this direction by a decision of the Supreme Court of the United States in what is known as the "Johnson Cancer Case," in which it was decided that under the terms of the Act as passed June 30, 1906, any false statement upon the package was regarded as applying only to the ingredients or substances contained therein. The Sherley Amendment, passed in 1913, was for the purpose of remedying this defect in the law which now applies to any statements concerning the curative or therapeutic effect of such medicines.

The prohibition of the law concerning the removal of the contents of the package, in whole or in part, and other ingredients substituted therefor, also strikes at a practice that has been all too prevalent in both the food and drug trade of the country. Certain popular and well-known products have been imitated in physical appearance, odor, and flavor, in the case of both drugs and foods, so that when the imitation was placed in the container of a well-known and largely advertised article, it became easy to deceive the purchaser. Such practice is not only fraudulent, but in the case of the imitation of drug products may be attended with serious consequences. It is, therefore, a most wise provision of the law which prohibits such practice under penalty.

Misbranding of Foods.—The provisions covering the misbranding of foods are, in principle, essentially those covering the misbranding of drugs, but in addition thereto, provision is made that all packages of food shall have a statement of the net weight thereon, and further provides that "compounds," "imitations," or "blends" shall be plainly branded as being such. The section also contains a proviso that in the case of "mixtures" or "compounds," which may now or from time to time hereafter be known as articles of food under their own distinctive names, and not an imitation of, or offered for sale under the distinctive name of another article, may be sold without further statement upon the label, if the name be accompanied with a statement of the place where such article has been manufactured or produced. This proviso has, in practice, been found to be the weakest place in food control, as it affords opportunity for articles to be sold under fanciful names which, through false or misleading statements in the advertising, are calculated to mislead or deceive the public as to their true character and value. Additional legislation, defining in clearer terms the meaning of a "distinctive name" and restricting in a more effective way, such compound food or drug product that may be unwholesome or detrimental to the public welfare, regardless of whether such ingredient was an "added" one, is imperative.

Wood Alcohol.—The use of wood or methyl alcohol is prohibited in all food and drug products in most States, although there are a number of products on the market containing wood alcohol which are still being permitted to be used as medicinal preparations for treating diseases of animals and as cosmetic preparations for use in barber shops. It seems to be the consensus of opinion that the use of methyl alcohol is dangerous in the extreme, not only because it is intensely toxic to the nerves of vision, but because many lives have been lost by people drinking extracts or toilet preparations under the presumption that they were made with ethyl or grain alcohol.

Preservatives in Foods.—The Act authorizes the Bureau of Chemistry of the U. S. Department of Agriculture to decide whether any food product contains any deleterious substance, and the Bureau is charged, in a general way, with the enforcement of the act. Soon after the law became effective, the Bureau held that the use of benzoate of soda as a preservative was detrimental to the health of those consuming food products containing this preservative. A storm of protest and criticism was raised by the manufacturers using this preservative, whereupon the Bureau undertook to make a practical test as to the effect of benzoate of soda on a number of young men who were fed upon foods containing certain definite amounts of the preservative. This group of young men afterward became known as "The Poison Squad." The result of the experiments as interpreted by the Bureau of Chemistry was that sodium benzoate is a substance that is deleterious to health, and that it, therefore, should not be permitted to be used as a preservative in food products. This decision was hotly contested by a large number of manufacturers, together with certain scientists who declared that the interpretation of the results of the experiment was not properly made. President Roosevelt, upon being appealed to, appointed a "Referee Board of Consulting Scientific Experts," whose duty it should be to investigate certain technical questions involved in the administration of the food and drugs act. Their special duty in relation to the investigation of benzoate is clearly set forth in the report of the board which is as follows:

"(1) Does a food to which there has been added benzoic acid, or any of its salts, contain any added poisonous or other added deleterious ingredient which may render the said food injurious to health? (*a*) In large quantities? (*b*) In small quantities?"

"(2) If benzoic acid or any of its salts be mixed or packed with a food, is the quality or strength of such food thereby reduced, lowered, or injuriously affected? (*a*) In large quantities? (*b*) In small quantities?"

Their report as made to Hon. James Wilson, Secretary of Agriculture, and published in U. S. Department Agricultural Report No. 88, is, in summary, as follows:

"To obtain satisfactory answers to these questions, the board has felt it necessary to carry through a careful investigation of the effect of benzoic acid or some one of its salts on the nutrition and general health of man. A thorough study of the literature giving the results of work done by various investigators on the physiological effects of benzoic acid and its salts, together with a study of reported clinical and medical observations, therapeutic usage, etc., have made it apparent that additional work was needed to render possible a conclusive answer to the above questions.

"With a view to limiting the scope of the work, while at the same time meeting all practical requirements, our investigation, with the consent of the Secretary of Agriculture, has been confined to a study of the effect of the sodium salt of benzoic acid, viz., sodium benzoate.

"To make this experimental inquiry as thorough as possible and to minimize the personal equation, three independent investigations have been carried out; one at the Medical School of Northwestern University in Chicago, under the charge of Prof. John H. Long, of that institution; a second at the private laboratory of Prof. Christian A. Herter, of Columbia University, New York City; and the third at the Sheffield Scientific School of Yale University, in charge of Prof. Russell H. Chittenden.

"The same general plan of procedure was followed in all three experiments. A certain number of healthy young men were selected as subjects, and during a period of four months these men, under definite conditions of diet, etc., with and without sodium benzoate, where subjected to thorough clinical and medical observation, while the daily food and the excretions were carefully analyzed, and otherwise studied, and comparison made of the clinical, chemical, bacteriological, and other data collected. (For details see the individual reports.) In this manner material has been brought together which makes possible conclusions regarding the effect of small and large doses of sodium benzoate upon the human system.

"In fixing upon the amount of sodium benzoate that should constitute a 'small dose' we have adopted 0.3 gram of the salt per day. Manufacturers of food products which, in their view, require the use of a preservative are in general content with 0.1 per cent. of sodium benzoate. This would mean that in the eating of such a preserved food the consumer would need to take 300 grams per day, or nearly two-thirds of a pound, of preserved food to ingest an amount of benzoate equal to our minimal daily dosage. Looked at from this point of view, our dosage of 0.3 gram per day seemed a fair amount for a 'small dose,' one that would clearly suffice to show any effect that small doses of the salt might exert, especially if continued for a considerable length of time. In all these three experiments this daily dosage was continued for a period of about two months. Under 'large dose' was included quantities of sodium benzoate ranging from 0.6 gram to 4 grams per day. Such a daily dosage was continued for a period of one month. In a few instances somewhat larger doses were employed.

"As the amount and character of the daily diet exert a well-known influence upon many of the metabolic or nutritive changes of the body, as well as upon the bacterial flora of the intestines, attention is called to the fact that the three investigations differed from each other in the amount of protein food consumed daily, thereby introducing a distinctive feature which tends to broaden the conditions under which the experiments were conducted.

"The conclusions reached as a result of the individual investigations are given at length in the separate reports herewith presented, together with all of the data upon which these conclusions are based. The fact should be emphasized that the results obtained from the three separate investigations are in close agreement in all essential features.

"The main general conclusions reached by the referee board are as follows: (1) Sodium benzoate in small doses (under 0.5 gram per day) mixed with the food is without deleterious or poisonous action and is not injurious to health. (2) Sodium benzoate in large doses (up to 4 grams per day) mixed with the food has not been found to exert any deleterious effect on the general health, nor to act as a poison in the general acceptation of the term. In some directions there were slight modifications in certain physiological processes, the exact significance of which modifications is not known. (3) The admixture of sodium benzoate with food in small or large doses has not been found to injuriously affect or impair the quality or nutritive value of such food.

IRA REMSEN, *Chairman*,
RUSSELL H. CHITTENDEN
JOHN H. LONG,
CHRISTIAN A. HERTER,
Referee Board of Consulting Scientific Experts."

The former decision of the Bureau of Chemistry was, therefore, overruled, and the Secretary of Agriculture, at the direction of President Roosevelt, made a supplemental order permitting the use of sodium benzoate for the preservation of foods, providing only that a statement be made upon the label indicating the presenceof such preservative when used.

In like manner, the question as to the use of sulphur dioxide, copper sulphate, alum, saccharin, borax or borates, and other preservative substances, has been referred to the Referee Board of Consulting Scientific Experts for determination as to their wholesomeness, or otherwise, when used in food products.

The chief objection to the use of benzoate of sodium or other chemical preservatives in food products is, that the addition of such preservatives makes it possible to use inferior and partially spoiled raw material in the preparation of food products; and this is said to be also an effective way to prevent the natural result of fermentation and spoilage which are sure to follow insanitary conditions in manufacturing establishments.

Guarantee Provision.—Section 9 provides that "No dealer shall be prosecuted under the provisions of this act when he can establish a guarantee signed by the wholesaler, jobber, manufacturer, or other parties residing in the United States from whom he purchased such article, to the effect that the same is not adulterated or misbranded within the meaning of the act designating it."

The purpose of this provision of the act is to fix the guilt on the real guilty party and to afford protection to the innocent dealer who, from the very nature of things, is often unable to determine as to whether an article of food or drug is adulterated or misbranded. The Bureau of Chemistry has provided, by regulation, a way in which each original package article may be guaranteed under the provisions of this section by issuing a serial number to manufacturers or jobbers which, when placed upon the label of an article, acts as a guarantee to the dealer to whom the article is sold. Theoretically, this seems to be an easy and certain way to fix responsibility on the guilty party and to protect the innocent dealer, but as a matter of fact, in actual practice, this so-called "Guarantee Legend" has been one of the most potent methods of deceiving the ultimate purchaser or consumer, in that the notion is almost universally prevalent that an article of food or drugs upon which appears the guarantee serial number legend is guaranteed by the government to be free of adulteration or misbranding, and thus, in many instances, the very intent and purpose of the law is defeated by this unfortunate measure.

A number of the States, following the lead of the Federal Government, provided for the issuance of guarantee serial numbers under their State laws, but the abuse of this guarantee legend was so apparent, because it was used for advertising purposes, and its effect was so misleading, that it has been discontinued by a number of states. At a conference of the State Food and Drug Control Officials with the Chief of the Bureau of Chemistry, held in Washington, D. C. in November, 1913, a resolution was adopted denouncing the use of the guarantee serial number, and requesting that it be discontinued at the very earliest possible date for the reasons above stated.

Seizure of Adulterated or Misbranded Products.—Section 10 of the Act provides "That any article of food, drug or liquor that is adulterated or misbranded within the meaning of this Act, and is being transported from one State, Territory, District, or insular possession to another for sale, or, having been transported, remains unloaded, unsold, or in original unbroken packages, or if it be sold or offered for sale in the District of Columbia or the Territories, or insular possessions of the United States, or if it be imported from a foreign country for sale, or if it is intended for export to a foreign country, shall be liable to be proceeded against in any district court of the United States within the district where the same is found, and seized for confiscation by a process of libel for condemnation."

It will be noted that this section, in contradistinction to the other provisions of the law, is a procedure against an article that is adulterated or misbranded. No hearing is required to be held, although it is necessary for the Bureau of Chemistry, or an agent or inspector acting under the authority of the Bureau, to determine by investigation as to whether or not the article in question is adulterated or misbranded.

When a procedure is started in the U. S. District Court in the jurisdiction in which the alleged adulterated or misbranded product is found, the United States marshal seizes the goods and they are then held under the authority of the court until trial of the case and verdict of the court. In case the article

in question is of a poisonous or deleterious character, it is the duty of the court to dispose of the article by destruction. If, however, it is simply a question of misbranding, or of non-deleterious adulteration, the goods may be restored to the owner upon filing bond with the court to the effect that such article shall not be sold or otherwise disposed of contrary to the provisions of the act, and, upon the payment of the costs of libel, the goods may be released. It has been found in practice that this is a wise provision of law because quick action can be taken against goods that are unwholesome or deleterious, and by seizure and condemnation, prevent such unwholesome or deleterious products to be sold to the ultimate consumer. Two modes of procedure are contemplated by the national food and drug act, first, criminal action against the person or persons violating the provisions of the act, and second, seizure and condemnation by libel of the articles that are adulterated or misbranded within the meaning of the act. Criminal action against those violating the law, as provided in the act, is often long delayed, while the goods may meanwhile find a market in the channels of trade, much to the detriment of the public welfare. A number of the States do not have a like provision in their laws, and are thus unable to seize and condemn goods which, in many instances, the protection of the public health would seem imperatively to demand.

Sanitary Aspects of Food and Drug Inspection.—One of the anomalies of our dual system of government is clearly shown in the limitation of the National Food and Drug Act to have sanitary supervision of persons and things, or the places where food and drug products are manufactured, stored, or sold. Sanitary control is essentially a police measure, and at the time of framing the federal constitution, all police powers were retained by the respective States, and thus the national government finds itself barred by the constitution in passing legislation which would give it sanitary supervision over places, persons, and things in their relation to food and drug production. It follows, therefore, that whatever sanitary control is exercised in this direction must be by the several States, and it has only been in very recent years that the States have recognized the importance of sanitary supervision in food control. The Association of American Dairy, Food, and Drug Officials at their annual meeting in 1911 adopted a model sanitary law, with recommendation that effort be made for its enactment in every State in the Union represented in the association. Accordingly, this law was presented to the respective legislatures and quite generally enacted into law by the respective States, so that, to-day, there are few States in the Union but what have laws giving to Boards of Health or food commissioners authority and power to regulate sanitary conditions in food and drug establishments.

It is quite generally admitted that most misbranding or adulteration is of a harmless character so far as public health is concerned, the question of fraud or deception being the chief element in either adulteration or misbranding, but it is, also, quite generally conceded that the sanitary conditions under which food and drug products are manufactured, stored and sold are of vital importance as affecting the quality and wholesomeness of the product and the health, not only of the employes handling such products, but of the ultimate consumer as well. It has long since been demonstrated that the mere passage of a law prohibiting the adulteration or misbranding of foods and drugs, or requiring places and things to conform to certain sanitary standards will not bring about the desired ends unless provisions are made for frequent personal inspection by trained inspectors. Recognizing this principle, every State where efficient food and drug control has been established, has qualified inspectors whose duty it is carefully to inspect all places and things as to their sanitary condition, and to secure samples of products for analyses to determine whether or not misbranding or adulteration exists. Thus, effective enforcement of the laws is brought about.

A sanitary inspection of a manufacturing establishment comprehends, (1) the character and quality of the raw material used; (2) the methods of manufacture and storage; (3) the sanitary condition of the manufacturing plant, including all appurtenances, and (4) the health of the employes working therein.

Most of the States have adopted a sanitary score card, which comprehends in the score the conditions actually found on the points above stated, and wherever insanitary conditions are found the law authorizes the inspector to make an order that within a certain stipulated and reasonable time, the insanitary conditions shall be abated, or certain specific improvements shall be made whereby the wholesomeness of the product may be safeguarded, and the health of the employes maintained. If, after the expiration of the reasonable period of time stated in the order, steps have not been taken to comply with the same, the law authorizes that information may be filed with the proper authorities for the enforcement of the law.

Both the national and the various State laws require that manufactured food products be made from sound, wholesome material. Fruits and vegetables that have fermented or have become decomposed, in whole or in part, or are dangerously polluted by pathogenic organisms, are not to be used for food purposes. It is also required that, where pieces or trimmings, or peelings and cores, or any other refuse materials are used, they shall be wholesome and fresh, and that the label on the container shall disclose the fact that the product is made from pieces, trimmings, etc., as the case may be.

Sidewalk display of perishable food products in retail establishments has been prohibited in most of the States, the law allowing only such food articles that are necessarily peeled, pared, or cooked before being consumed, to be displayed upon the sidewalk, or on the store floor, provided that such articles are displayed at least eighteen inches above the sidewalk or floor. The model sanitary law, also, provides that all perishable foods be effectively protected by screens or coverings from the possible contamination of dust or flies.

Proper toilet facilities are required in all food producing establishments, and abundant facilities are required for the proper washing of the hands of all employes after visiting the toilet before returning to work.

The wholesomeness of the water supply, as well as the sewage disposal, is inquired into, and definite standards are applied to the proper installation of wholesome water supply and proper sewage disposal.

Meats are required to be covered in transit from the slaughtering establishments to the markets or shipping places, and only such cars are to be used for the shipping of food products as are reasonably clean, in order that such products may not be dangerously contaminated by polluting organisms or foul odors or flavors.

Physical Examination of Employes.—The one great defect in securing absolute freedom from dangerous contamination of food products is that of inability, up to the present time, to require definite knowledge that all persons handling food products are free from communicable disease. It is believed the next great reform movement in food control must be along this line. In Kansas, the State Board of Health has recently secured the cooperation of the large meat packing establishments in requiring that all employes handling meats or meat products be required to pass a physical examination for communicable disease of any kind, including tuberculosis and venereal disease, before they can either find

employment or be permitted to continue in the employment of these establishments.

In 1912 the largest hotel in the city of Indianapolis put into effect a like requirement and gradually, by the force of public opinion and the insistence of boards of health, this great desideratum in safeguarding the wholesomeness of food products is being brought about.

Inspection of Meats.—The federal meat inspection act provides for the antemortem and postmortem inspection of all animals slaughtered for food that are shipped in interstate trade, and regulates the manner of labeling all meat food products. Indirectly the federal government exercises sanitary supervision of federal-inspected meat packing plants by requiring certain sanitary conditions to prevail before installing a system of federal inspection or, after once having been established, if insanitary conditions continue to prevail, by withdrawing federal inspection. The last report of the Bureau of Animal Industry indicates that approximately sixty-five per cent. of the animals slaughtered for food purposes in this country are slaughtered in federal-inspected packing establishments, leaving thirty-five per cent. slaughtered in local slaughter houses not engaging in interstate trade, and which are not under local inspection, except in a few isolated instances where municipal abattoirs have been established. The very fact that animals that are diseased, or are unfit for food for any reason, are condemned by the federal-inspected slaughterhouses tends to divert such diseased animals to establishments having no inspection, and thus the importance of local meat inspection for all slaughtering establishments is emphasized. If there is a reason for inspecting sixty-five per cent. of the animals slaughtered for food purposes, there can be no possible reason for the remaining animals thus slaughtered not having effective inspection.

Local Inspection of Perishable Products.—Such articles of food supply as milk, meats, bakery products, and perishable fruits and small vegetables that are sold at or near the point of production must, in the very nature of things, be inspected by State, or better yet, by municipal authorities, if a perfect system of food control is established. There may come a time, and probably will, when, in municipalities, trained sanitarians will have the care of local food problems, but until that time arrives, the State with its better organized forces, better equipped laboratories, and more highly trained men must assume control and provide for the safeguarding of all food supplies, after they have passed from federal jurisdiction, or city regulation, and are distributed wholly within the State limits.

It is believed that food and drug control is essentially a public health problem, and should properly be made a function of the State Department of Health, but strangely enough in most of the States this division of the State's service is under separate food commissions or the agricultural department, or under dairy commissioners. Such officials may well regulate the sale of oleomargarine, and improve the quality of the milk supply, but they can hardly be expected to be in touch with modern sanitary problems, and have a keen appreciation of the necessity for absolute sanitary conditions in the production and handling of food products to safeguard the public health.

Health officers are primarily interested in the character of the milk supply, not because they wish to build up a dairy industry, but because they know that pure milk means decreased infant mortality. They are interested in sanitary slaughterhouses, not that the butchers may have a profitable business, or that the production of beef and pork may be increased, desirable as that may be, but because they know that the sale of diseased meat and meat handled under insanitary conditions is a menace to the health of the consumers. They know that pure water means freedom from typhoid fever and dysentery; that the cook or baker suffering from tuberculosis is earning a living under conditions which are a menace to the health of his patrons, and that venereal disease must be stamped out if the consumers are to be assured clean foods. Food officials must assume the responsibility, not only of enforcing the laws, but of educating the people in the basic principles that make legislation necessary, and pointing out clearly and definitely the economic principles that are behind pure food and the ultimate danger that lies in impure food.

False Advertising.—It is becoming increasingly evident that the enactment and fairly efficient enforcement of the national and State food and drugs laws has not secured to dealers and consumers freedom from fraud and deception in food and drug products.

False and misleading statements, designs, and devices that appear in any place other than upon the label attached to the package, or the false and deceptive methods used by designing agents, salesmen, or manufacturers cannot be reached or prevented by resort to the food and drugs law, and thus, in many instances, the public continues to suffer by reason of gross misrepresentation of one kind or another. Take, for illustration, the false, extravagant, and, in their final effect, often harmful claims of many of the fake nostrums and appliances which appear in glaring advertisements in newspapers, circulars, or pamphlets, or are given by word of mouth by an agent to a prospective customer—in such cases the food and drugs law is powerless to protect the purchaser.

Drugs and medicines, food products, and beverages should be sold for exactly what they are, and false representations of any kind are frauds upon the purchaser. It is for this reason that a false advertising law is imperatively necessary as a supplement to the food and drugs law. S. J. Crumbine.

Food Poisons.—From the earliest time poisoning from diverse foods has attracted the attention of the laity and of medical men. Numerous explanations, many of these decidedly absurd as viewed from the standpoint of our present knowledge, have been put forth, and it is only within comparatively recent years that vague hypotheses have given way to exact chemical and bacteriological studies. As a result, a flood of light has been thrown upon the causation of food poisonings, and the observations thus made have in turn served their purpose of indicating the relatively simple means by which many of these intoxications may be avoided.

Individual susceptibility plays a most important part in all poisonings. It is very well known that a given poison may affect two individuals in a wholly different manner. Moreover, observations are not wanting which show that a substance which we may have good reason to consider as wholly innocuous is nevertheless very deleterious to some. The fortunately very rare instances of fatal results following the injection of antitoxic sera may be taken as an example of such idiosyncrasy—hypersusceptibility. In like manner one may meet with individuals to whom a given article of food invariably plays the part of a poison, and justifies the oft-quoted adage that "what is meat to one is poison to another." The use of veal by some and of eggs by others, is often followed by distressing symptoms. The cleavage products of such foods, whether due to defective metabolism or to an anaphylactic reaction, are in the main responsible for the ill effects experienced.

While idiosyncrasy has to do with a single individual, there are on the other hand hundreds of instances of "food epidemics" where an extraneous cause must be sought for. In the latter cases the food or article consumed has acquired in some way marked poisonous properties, and in so far as the origin of this poison

is concerned it may be spoken of as *endogenous* or *exogenous*.

Those articles in which the poison is of endogenous origin can hardly be designated as foods, although it may be very convenient to speak of them as autopoisonous. The poisonous mushroom, for example, is often mistaken for an edible form. The two kinds are wholly distinct, and the former is injurious because it normally produces highly poisonous products, such as the alkaloid, muscarine. In like manner the blood of eels is toxic, because of the presence of preformed physiological products. Some animals, especially molluscs and fish, are popularly believed to acquire poisonous properties at certain phases of sexual life. However, it is very certain that there are fish which when perfectly fresh are highly poisonous. Just as the poisonous mushroom is capable of elaborating its specific poison, so certain fish are similarly endowed and give rise to normal physiological but toxic products. The nature of the products elaborated in the tissues of such poisonous fish is not fully known. They are believed by some to be leucomains or basic alkaloidal substances formed by the peculiar cell metabolism. Intoxications which are due to fish which are poisonous in and of themselves are of common occurrence, especially in the West Indies and in Japan. It is to this class of poisonings that Blanchard has applied the term *siguatera*, to distinguish it from the more ordinary food poisonings of exogenous origin.

The exogenous origin of food poisons is by far the most common occurrence. Under this head are to be placed all those articles of food or consumption which are ordinarily perfectly wholesome and which only occasionally, and then through what may be designated as an accident, acquire injurious or poisonous properties. The poison or injurious element in such cases is of foreign origin, and it is because of the introduction and presence of such poison in a food that the unexpected manifestations of intoxication are observed.

The food poisons of exogenous origin may be discussed under three heads: (1) Poisonous compounds; (2) animal parasites; (3) vegetable organisms, including bacteria and fungi.

With reference to the first head, that of poisonous compounds, which includes metals and organic bodies, it may be said that they play as a rule only a very secondary rôle in outbreaks or epidemics of food poisoning. The metals which are supposed or have been shown to be the active cause of poisonings are arsenic, antimony, tin, lead, zinc, and copper.

An interesting instance in which arsenic and antimony were the cause of fatal poisoing in animals was noted several years ago by Vaughan. In a Western mining region where hydraulic mining was practised, the disintegrated ore deposit was washed down into a river, the water of which as a result became highly charged with soluble and suspended arsenic and antimony compounds. A much more notable instance, however, of poisoning of this kind is that recently (November, 1900) observed in Manchester, where a widespread epidemic of peripheral neuritis followed the use of beer which on analysis was shown to contain appreciable amounts of arsenic. The arsenic in this case was derived from the sulphur ores which were used in the manufacture of sulphuric acid. The latter, in turn, with its unknown arsenic contents, was employed in the preparation of the glucose, and it was through the glucose that the metal found its way into the beer.

Lead poisoning which follows the use of water which is conveyed through lead pipes is a well-known fact. An unusual instance of intoxication was reported in 1887 by Stewart. A Philadelphia baker ignorantly used lead chromate as a substitute for eggs to color his dough. The buns prepared with this material are known to have caused sixty-four poisonings, eight of which proved fatal. A somewhat similar mistake is that reported many years ago by Ungefug, who found that a large quantity of zinc sulphate had been used in place of the preservative saltpeter.

In articles of food which have been kept for some time in tin cans, or in zinc or copper vessels, traces of these metals can be invariably expected, and while unquestionably these metals in large doses are poisonous, it is nevertheless true that they have little or nothing to do with the acute poisonings so often observed. The bare possibility of canned foods being poisonous as a result of the presence of these metals may be conceded, but the occurrence of such is very doubtful indeed. In such cases it can be shown that bacterial decomposition has taken place, and while it is possible for the organic acids produced by such decomposition to dissolve the metals, still true bacterial poisons may be present and should be looked for. This can be done only by studying the effects produced by pure cultures of the organisms present in such food.

Poisonous organic substances may at times be introduced into food or beverages through ignorance of their action. Thus, the dilution of cognac with methyl alcohol resulted in a severe outbreak of poisoning in Berlin in 1911–12. Another example of wide-spread poisoning of this type developed in Altona (1911) consequent upon the consumption of an oleomargarine which contained a large amount of maratti fat.

Food poisoning as the result of the presence of animal parasites has been a recognized fact ever since the discovery of trichinæ in the flesh of hogs. It is very important in suspected poisonings when pork or pork sausage has been eaten, to make a careful search for trichinæ. This should be done before a chemical and bacteriological examination is undertaken. Like trichinæ, other animal parasites, notably those of the intestines, may be introduced with the food, but these occurrences are rarely considered under the head of food poisons, and for that reason need no extended consideration in this connection.

Vegetable organisms constitute by far the most common cause of food poisoning. It will be presently shown that certain moulds or fungi thriving especially on plant food may render these injurious. Apart from these isolated and in this country largely unknown intoxications, it may be said that bacteria are the only type of vegetable life which are concerned in the vast majority of food infections. Dead animal or vegetable matter is prone to invasion by bacteria and putrefaction or fermentation, as the case may be, is soon established. To use an axiom of Claude Bernard's, "death is life," and the life thus established in dead matter under favorable conditions is seen in the myriads of the tiny workers, whose duty it is to break up and transform the complex organic substances present in plants and animals and return their elements to the inorganic world. The bacterial invasion of wounds finds its analogue in the bacterial invasion of foods, and just as cleanliness and asepsis obviate the former, so proper storage and thorough cooking will prevent the latter. Of the large number of different kinds of bacteria which may find lodgment in a wound only a few perhaps are capable of producing poisonous products. This fact is likewise true of those bacteria which invade dead plant and animal matter. The mere fact that a food, solid or liquid, contains enormous numbers of bacteria does not indicate that it is poisonous. The vast majority of bacteria are harmless organisms which elaborate simply non-poisonous products. On the other hand, a relatively small number of bacteria are capable of making poisonous products, and to these organisms the term *toxicogenic* may be applied.

Inasmuch as bacteria, when injurious, produce their ill effects by means of the poisons which they elaborate, it is desirable briefly to touch upon these products. The term *ptomaine* was introduced in 1876 by the Italian chemist Selmi to designate basic alkaloidal products formed in putrefaction. Bearing in mind the

fact that strychnine and muscarine are intensely poisonous vegetable alkaloids, it was quite natural to explain the profound intoxication met with in infectious diseases and in the poisoning from foods by assuming that bacteria elaborated similar toxic alkaloidal products. It is largely through the labors of Brieger that our knowledge concerning ptomaines was gained. A considerable number of these basic alkaloidal products were isolated. The mytilotoxin found in poisonous mussels is of this class and is by far the most poisonous of the known ptomaines. As a rule these substances are but feebly poisonous or not at all, and it follows that in such instances some other poison non-basic in character must be present. The term "ptomaine poisoning" has been popularized to such an extent that it is used synonymously with food poisoning. The fact is that in only very exceptional instances are ptomaines to be credited with being the cause of such poisoning.

The study of snake venom showed that the active poison in that secretion was an albuminous substance. Like investigations made with the seeds of jequirity and with the castor bean showed the presence of other poisonous protein bodies. Brieger and Fraenkel in 1889 examined highly poisonous diphtheria cultures, and from these they obtained very poisonous precipitates which being protein in composition were designated as *toxalbumins*. The same method of examination soon revealed the presence of toxalbumins in cultures of other disease-producing bacteria. In a very short time, however, it was shown that the so-called toxalbumin was not a definite chemical substance but rather a mixture of an inert protein and an active poison non-protein and non-basic in character. To distinguish the real poison from ptomains and from the so-called toxalbumins it has been designated as the *toxin*. After all, this is merely a term for an as yet unknown or rather but as yet imperfectly known substance. The toxins of diphtheria and of tetanus have been studied the most, but beyond a general knowledge of their reactions and behavior nothing is known as to their structure or composition. One thing is certain, that in the toxin many bacteria possess a most deadly weapon. Brieger and Cohn, after purifying the tetanus toxin, for example, as much as possible, found that the extremely minute amount of 0.00000005 gram killed mice. A similar and almost equally destructive toxin has been separated from cultures of the *Bacillus botulinus* obtained from some poisonous ham. This product will be presently discussed at some length.

Recognizing the fact that bacteria are the cause of the majority of food poisonings and that they induce their poisonous effects by means of the toxins which they elaborate, it is of interest to inquire into the formation of these products. While many toxicogenic bacteria, especially including the disease germs, are capable of growing at the temperature of the body, there are those which cannot do so. The latter are therefore incapable of growing in the body. The poisons which such organisms elaborate must of necessity arise in the food, while this is kept at the ordinary room temperature. The effects which follow the eating of such food will necessarily vary directly with the quantity of the food taken, since the active poison is made wholly outside of the body. Ballard's Iron Bridge cases are instances of this kind of poison production, for in these the specific germ would not grow above 86° and its cultures at 60° were markedly poisonous. The same is true, as will be presently shown in poisoning with food which contains the *B. botulinus*. The organisms at work in such cases, although toxicogenic, are nevertheless practically obligative saprophytes. Poison production then may take place (1) wholly outside of the body. On the other hand, (2) given an organism which is capable of growing at the body temperature as well as at the room temperature—in other words a facultative parasite—it follows that such an organism, having begun the production of poison outside of the body, in the food, may continue to elaborate like poisons in the intestines after such food is taken. While in the first instance the effects are those of a plain intoxication following the introduction of a ready-made poison, in this case intoxication and infection are combined. A third type of poison production is shown when the organism present in the body is truly pathogenic. It may be present in but very small numbers in the food and the poisonous products made therein may be practically nil, yet disease may follow. In other words, a true infection results from the presence in the food of disease-producing organisms. Contamination of drinking-water or milk with cholera, typhoid bacteria, streptococci, etc., would fall under this head. More directly, however, this group will include bacterial diseases of animals which may be transferred to man through the flesh of animals so diseased. This type of food poisoning, it will be seen, is analogous to that with animal parasites.

From what has been said it is evident that the greater part of food poisonings are instances of food infection. Such food either was at first perfectly wholesome and through improper handling became contaminated with poison-producing bacteria; or, derived from diseased animals, it already contains the specific harmful germ. In view of the undoubted fact that the germs producing these poisons are very rarely the same in two distinct outbreaks, it follows that the poisons are different and as a consequence the symptoms observed will vary within very wide limits. It is not reasonable or in accordance with known facts to believe that in poisonous cheese, for example, only one and the same organism is always present and that the chemical poison is the same in all intoxications from such food. A considerable number of organisms undoubtedly, if the opportunity is given for their development in cheese, are capable of rendering it poisonous. In like manner, poisonous meats, sausage, and fish do not owe their toxicity to any one specific organism. Already a number of toxicogenic bacteria have been isolated during the past two or three decades from different outbreaks of meat poisoning. This number will of necessity be increased as more careful methods come to be employed in the study of these accidental poisonings. As will be shown, the organisms most commonly causing meat poisoning belong to the so-called paratyphoid group, intermediate between the colon and typhoid bacilli.

Poisonous Meat.—Every kind of meat which man is accustomed to use as food is liable to become poisonous. Raw or improperly cooked meat is usually responsible for the occurrence of such results. The frequent occurrence of sausage poisoning in Germany led to its designation as botulismus or allantiasis. These terms, however, may be used so as to embrace any meat poisoning, but it is preferable to retain the original meaning of botulismus and following the nomenclature of Vaughan to designate meat poisonings, regardless of form or origin, as *Kreatotoxismus*.

Bacillus Botulinus.—By far the best studied instance of meat poisoning is that recorded by Van Ermengem. The outbreak occurred in the Belgian village of Ellezelles and at first affected thirty-four persons who were all members of a musical society. A few days later a number of other persons became sick with the same symptoms. Three of the persons afflicted died within a week. The investigation which took place showed that the sick people had all partaken of a certain ham. The hog from which the meat was prepared was perfectly healthy and at the time of slaughtering a portion of the meat was eaten raw without any effect following. After salting, both hams and other portions of the animal were packed away. The brine used was clearly deficient in salt and insufficient in quantity, since only the bottom ham was immersed in the liquid.

The upper portions of meat were consumed without any ill effect and it was only the immersed ham which caused the poisoning. This exclusion of air as well as the deficiency of salt allowed the development of an anaërobic bacillus to which Van Ermengem applied the name *B. botulinus*. It may be remarked in passing that Kempner obtained the same organism from the feces of a hog.

The symptoms observed in this outbreak were shown to be due to a toxin elaborated by the bacillus in the ham. The lateness in the onset of the symptoms and the absence of fever were rather remarkable for a true intoxication. As a rule no effects were observed during the first twenty-four hours after the meal and in some cases the onset was delayed for thirty-six hours. Gastric pains with repeated vomiting were first observed. With the exception of two cases all had an obstinate constipation. The gastrointestinal symptoms were not so marked as in most instances of food poisoning, but the nervous symptoms were especially pronounced. All showed characteristic disturbances of vision. The eyes became fogged and in a short time recognition of people failed. Diplopia set in. Marked dilatation of the pupils with total loss of reaction as well as ptosis of both eyelids followed. Added to this was the sensation of a burning thirst and a constriction of the throat. The latter at times was so marked as to render the swallowing of even liquids difficult. The mucous membranes were strongly reddened, and in some the abundant secretion of viscid mucus led to violent attacks of coughing and even of suffocation. At times complete aphonia and anuria were observed. Extreme muscular weakness was general. In spite of these severe symptoms the pulse remained below 90, the respiration and temperature were normal. In fatal cases coma or mild delirium occurred. The recovery was very slow and extended through several weeks and even months.

Feeding of the ham or of macerations made with it proved fatal to mice, white rats, young cats, guinea-pigs, and monkeys. Subcutaneous injections of 0.001 c.c. of the maceration (1 to 5) killed mice. In larger doses it was fatal to rats, doves, and cats. Rabbits were extremely susceptible, while frogs, dogs, and chickens were refractory. The fact that the maceration after being filtered through porcelain was as active as when unfiltered showed that a soluble toxin existed in the ham. The further fact that the bacillus was not present in the organs of the animals that died after inoculation showed that it was a true saprophyte, although markedly toxicogenic.

The toxin of *B. botulinus* in its activity resembles that of tetanus or diphtheria. It is promptly destroyed by boiling but not by putrefaction. Marinesco found that the lesions produced by this toxin are largely confined to the cells of the gray matter of the cord. With very small doses the lesions consist of a rarefaction of the chromatophil elements. Under the influence of larger amounts of poison the granules of Nissl undergo more or less marked disintegration or chromatolysis. When fatal doses are administered some of these cells will be found to be completely destroyed. Kempner has successfully immunized a goat against the action of the toxin and obtained an antitoxic serum of marked potency.

Non-febrile intoxications with pronounced nervous symptoms accompanied by obstinate constipation have been repeatedly observed in the past in connection with sausage poisoning, and it is quite possible that a similar, if not identical, toxin to that just described was the cause. A noteworthy instance of this kind was furnished by the observation of von Faber, who reported in 1821 an outbreak which caused the death of five out of sixteen people who had eaten fresh unsmoked pork sausage. There were constriction of the throat, difficulty in swallowing, retching, vomiting, colic-like pains, vertigo, hoarseness, dimness of vision, and headache. Later on, in the severe cases, there was complete exhaustion, and finally paralysis. The eyeballs were retracted, the pupils were sometimes dilated, then contracted, and did not respond to light. The upper lids were paralyzed. The tonsils were swollen, but not as in tonsillitis. Liquids which were not irritating could be carried as far as the esophagus, when they were ejected from the mouth and nose with coughing. Solid foods could not be swallowed. On the back of the tongue and in the pharynx there was observed a puriform exudate. Obstinate constipation existed in all, while the sphincter ani was paralyzed. Breathing was easy, but all had a croupous cough. The skin was dry and there was no incontinence of urine. There was no delirium and the mind remained clear to the last.

Since the epoch-making study of Van Ermengem, the *B. botulinus* has been isolated in poisonings by several workers. Römer, ham (1900); Landmann, canned beans (1904); Schumacher, ham (1912). It was undoubtedly responsible for the fatal poisonings at Sawtelle, Cal., ascribed to canned pears, and reported by Peck (1910). The prognosis in this type of poisoning, because of the severe injury to the central nervous system, is unfavorable. Fortunately, such intoxications are extremely rare.

As a rule, intoxications resulting from sausage and other foods are characterized by a febrile gastroenteritis in which recovery usually occurs. Thus, in the Wellbeck cases reported by Ballard the temperature at times rose to 103° and 104° F. and the diarrhea was quite unrestrainable. Muscular weakness was an early and marked symptom and the debility of convalescence was in nearly all cases protracted to several weeks. Intense and distressing thirst with nausea and vomiting was quite general. These symptoms varying in degree and duration, from a few hours to several weeks, are present in all meat poisonings other than that of botulismus.

The cause of this type of poisoning is not a single organism, as in the case of botulismus, but rather one of a group. This fact will be readily understood when it is remembered that the bacterial invasion of the meat may occur postmortem, in which event, obviously, various organisms can be found. On the other hand, such invasion may occur during life, that is, the animal is diseased at the time of slaughtering, and here also different organisms may be at work. The use of condemned, diseased animals is certainly the most frequent cause of meat poisonings in Germany.

The earliest study of poisonous meat by modern bacteriological methods was made by Gaffky and Paak in 1885. From the meat which came from a diseased horse they isolated a colon-like bacillus to which Kruse subsequently gave the name *B. friedebergensis*. Three years later came the important contribution by Gärtner which definitely drew attention to the bacterial cause of meat poisoning.

Bacillus Enteritidis.—This name was applied by Gärtner to the organism which he isolated in 1888 from meat which had poisoned a large number of persons. The same organism was also isolated from the spleen of a man who died from the effects of the meat poisoning. The meat was unquestionably infected from the beginning, inasmuch as the cow which furnished it had a severe diarrhea for some days before she was killed. Of the fifty-eight people who were rendered sick one died. The effects observed were those of a pronounced gastroenteritis with subsequent desquamation. These symptoms occured in persons who had eaten the cooked meat as well as in those who had taken it raw. On feeding animals with sterilized cultures of this bacillus, Gärtner was able to show that such cultures were highly poisonous. Guinea-pigs thus fed died in anywhere from a few hours to five days. Mice similarly fed died in a few days. It is noteworthy that unlike Van Ermengem's toxin, which is readily destroyed by heat, the cultures of Gärtner's bacillus maintain their toxicity even after boiling for several

hours. The poison then is very resistant to heat and resembles in this respect the intracellular toxins of the colon bacillus which have recently been studied by Vaughan. Morphologically the *Bacillus enteritidis* is closely allied to the colon bacillus, from which, however, it differs in not producing indol and in its pronounced infectiousness even when fed to animals.

The same organism, or at all events one closely allied to it, was isolated in 1891 by Lubarsch from the lungs and spleen of a child who died of what was diagnosed as Winckel's disease. Karlinski has also succeeded in isolating this bacillus from a case of food poisoning which came under his observation. Fischer likewise met with what he believed to be Bacillus enteritidis in an outbreak of food poisoning which affected nineteen persons.

In a case of food poisoning studied by Johne the *B. enteritidis* was also found. The same organism was met with in all probability by Poels and Dhont, Holst, and Günther. The food poisoning reported by Günther in 1897 affected some twenty-six or twenty-seven families and was due to the eating of pork, as well as to the sausage and blood derived from the same. Abdominal pains, vomiting, diarrhea, and extreme weakness were the symptoms observed. Only one person died, and from the internal organs of this individual Günther isolated the *B. enteritidis*. It was assumed that this organism was present in the poisonous food, but all efforts to isolate it from the latter failed.

Another instance in which presumably the *B. enteritidis* was involved was observed by Silberschmidt in 1896. Organisms apparently identical with *B. enteritidis* were isolated by Basenau (1893), Kaensche (1893), and by Van Ermengem. The latter found it in an epidemic at Ghent (1892) and again at Morseele (1895). Since that time this organism has been frequent'y found in Germany, England, and elsewhere. A study of all the meat poisonings occurring in recent years shows that fully one-third of them are due to the *B. enteritidis*. The majority of meat poisonings, however, are identified with the presence of another organism, *B. paratyphosus* B.

Culturally and morphologically, the organisms isolated from various meat epidemics may be said to be identical. With the introduction of the serum agglutination test it became possible to differentiate more satisfactorily, and at the same time establish the causal relationship of the suspected organism with the outbreak. Thus, de Nobele found that a bacillus which he isolated from an outbreak at Aertryck (1898) agglutinated with the sera of the sick persons even in a dilution of one to four hundred. The sera of normal persons and of other diseases had no effect. The Aertryck bacillus while sharply differentiated from *B. enteritidis* and *B. typhosus*, by the agglutination test, was found to behave exactly like the hog cholera bacillus, *B. suipestifer*. It is believed to be identical with the latter which formerly was considered to be the cause of hog cholera but has since been shown to be a secondary invader in that disease.

The studies of Gwynn in this country, and of Schottmüller and others abroad demonstrated that paratyphoid fever was due to the paratyphoid bacilli A and B. It was then shown that the immune serum obtained with type B readily agglutinated the Aertryck bacillus but had little or no action upon *B. enteritidis*. The apparent identity of the Aertryck or hog cholera bacillus with *B. paratyphosus* B has led to the prevailing view of the identity of paratyphoid fever and meat poisonings.

By means of the agglutination test, the organisms isolated from meat poisonings can be separated into two groups (1) the *B. enteritidis* group which includes the Gärtner bacillus and a number of rat viruses, such as Danysz, Dunbar, Issatschenko, ratin, etc., and (2) the paratyphoid group, also spoken of as the "hog cholera" or "Salmonella" group, which includes *B. paratyphosus* B., B. suipestifer (hog cholera), *B. psittacosis*, *B. typhimurium*.

By supplementing the agglutination test in the tests for the absorption of agglutinins (Castellani) and for complement fixation, Bainbridge believes it possible to distinguish the otherwise identical hog cholera and paratyphosus B bacilli. As a result, he arrives at the conclusion that paratyphoid fever and meat poisonings are etiologically different. The former being due to the A and B strains of *B. paratyphosus* while the latter are due to *B. enteritidis* and *B. suipestifer* (hog cholera). Whether this differentiation holds or not, the fact remains that the vast majority of meat poisonings are due to one or the other of these two closely related organisms.

As pointed out, heretofore, postmortem invasion of meats by bacteria may lead to poisoning when such food is eaten raw or imperfectly cooked. Various bacteria, other than those discussed above, may be encountered under these conditions. It will be sufficient to present a few illustrations of this type of poisoning.

Ballard has reported a number of outbreaks of meat poisoning. Beef, canned pig's tongue, jellied pig's head, pork, ham, veal pie, pork pie, and canned sardines were the respective causes in these several outbreaks. It is interesting to note that the "Middlesborough pneumonia epidemic" which caused four hundred and ninety deaths, is attributed by Ballard to poisoning with imported bacon. He believed that the disease developed in a person who had eaten of the infected food and was transmissible from the sick to those who had not partaken of the infected food. In the lungs Klein found a short, thick bacillus which he called *Bacillus pneumoniæ*. This germ was different from the bacillus of Friedlaender and from the diplococcus of Fraenkel. Fourteen out of the twenty samples of bacon when fed to rodents produced death with lesions similar to those observed in man. During the progress of the investigation an epidemic of pneumonia broke out among the animals and in these the same organism was found. The poisonous bacon when kept for three months lost its toxicity and no growth of the bacillus could be obtained.

In 1894 Vaughan and Perkins examined some dried beef which had quite seriously poisoned a family of four. There was nothing in the appearance or odor of the beef to cause any suspicion. In fact it seemed to be of exceptionally good quality. Anaërobic cultures from the interior of the meat gave a colon-like bacillus which was pathogenic to white rats, rabbits, and guinea-pigs. The sterilized cultures were also poisonous. In an outbreak which occurred in Sturgis, Michigan, in the same year, a large number of men were rendered ill after partaking of pressed chicken. All were taken, within two to four hours after eating the chicken, with nausea, violent griping, and purging; many fainted while attempting to rise from bed. From the food Vaughan and Perkins isolated a slender bacillus and a streptococcus. The former proved to be very fatal to experimental animals. Anaërobic cultures were much more powerful than aërobic ones. It may be added here that cocci have been isolated from poisonous meats by other observers, notably Kühl, Bainbridge, and Sacquèpée.

A number of food poisonings have been investigated in which the causative organism has been shown to be in all probability the *Proteus vulgaris* or its related species. Thus Levy, in 1894, investigated a case of this kind. The keeper of a restaurant and some of his guests suffered from a most violent purging, which in the case of the host terminated fatally. *Proteus vulgaris* was isolated from the vomited matter, from the stools, and from the ice-box where the food was kept. Levy sought to demonstrate that the poison in this case was identical with the sepsin of Schmiedeberg. Wesenberg in 1897 studied a food epidemic which affected sixty-three persons. The

suspected meat came from a cow that was slaughtered when sick. Violent headache, intense abdominal pains, dizziness, extreme muscular weakness, and diarrhea were the symptoms noted. The greenish or brownish discharges were very putrid. The more or less decayed meat yielded a bacillus which Wesenberg believed to be indentical with *Proteus vulgaris*. It remains a question, however, whether this germ was the actual cause of the intoxications.

Silberschmidt reported similar results from an epidemic which occurred in a Swiss canton in 1899. In this instance forty-five persons were affected and one death resulted. The symptoms came on within twenty-four hours after eating "Landjäger" sausage, made out of beef and pork fat. The animals were apparently perfectly healthy. The taste and appearance of the sausage were faultless. Cultures made from the sausage gave *B. coli* and *Proteus vulgaris*. The etiological relation of the latter organism to the poisonings was by no means clearly demonstrated.

A somewhat similar outbreak was investigated in 1900 by A. Pfuhl. A "beef sausage" made by chopping up finely and potting the entrails, hearts, lungs, and spleens of three cattle was the cause of an acute gastroenteritis in eighty-one soldiers. The material fed to rats and mice induced diarrhea and gradual paralysis of the limbs, but the animals recovered. One of the mice was killed and from it Pfuhl isolated a bacillus which he identified with *Proteus mirabilis*. Pure cultures of the germ fed to mice caused death whereas rats recovered. The organism when inoculated into fish formed capsules but not otherwise. The toxin was destroyed on heating to 60° C. The dead bacilli were shown to be as toxic as the living, indicating that the poison was largely intracellular.

Other examples of Proteus findings in poisonous sausages have been reported by Pergola, Gutzeit and others. Bearing in mind that *Proteus vulgaris* is one of the common putrefactive organisms, it is not surprising to find that Zweifel was able to isolate this organism in 165 out of 248 portions of perfectly sound chopped beef.

In the above instances the demonstration that the poisoning was due to the Proteus group is far from perfect. There is no question but that these organisms are toxin producers, but that fact and the detection of such organisms in a food does not prove that they are the cause of the poisonings observed. Nevertheless, it may be well to indicate that at times proteus infections have been met with in man and that several observers have ascribed epidemics among fish to this same group. These will be presently touched upon.

Poisonous Fish.—In those countries where fish is the chief form of animal food it not infrequently gives rise to severe outbreaks of acute poisoning. Just as sausage poisoning is of relatively frequent occurrence in Germany so fish poisoning in Russia is equally common. In this country poisoning from canned fish has been repeatedly observed. As in the case of meat, fish may become poisonous as a result of being diseased; or, improperly preserved, the otherwise wholesome fish may become infected with saprophytic toxicogenic bacteria. In the one case the organisms are present during life and in the other they are introduced after death. On the other hand, it is well to remember that some fish are always poisonous either as the result of the presence of poisonous glands or as a result of eating certain kinds of food, while others may become poisonous during the spawning season. In such instances the toxic condition is normal and physiological. It is this form of poisoning which is designated by the Spanish physicians of the West Indies as *siguatera*, to distinguish it from the bacterial poisoning or botulismus. It is preferable, following the classification of Vaughan, to designate fish poisoning as *ichthyotoxismus*.

Epidemic diseases among fish have been observed by a number of investigators. Thus Charrin, in 1893, isolated several organisms which were pathogenic to fish. Emmerich and Weibel in the following year described the Bacillus salmonicida as the cause of an epidemic among trout. Sieber, in 1895, found that the fish in an aquarium, from which some had been taken to supply a table and had proven poisonous, were sick and that as many as thirty died within the next two days. From the dead and sick fish she isolated a highly toxicogenic germ to which she has given the name *Bacillus piscicidus agilis*. From cultures of this bacillus she isolated cadaverin and other known ptomains, besides which at least two undetermined bases were present. Sieber found the same germ in the dejections of two cholera patients. In 1898 Wyss reported the results of his study of an epidemic which prevailed among the fish in Lake Zurich. From the diseased fish he isolated an organism which he believed to be identical with Proteus vulgaris, although there were slight differences, such as the non-coagulation of milk, and non-decomposition of urea. Moreover, Wyss believes that the abovementioned Sieber's bacillus is identical with that isolated by him and hence is also a *Proteus vulgaris*. That fish infected with this germ, if eaten in a partially cooked state, may cause poisoning in man is seen in Sieber's observation, and in the fact that proteus infections of meat have been described by Levy, Wesenberg, Pfuhl, Silberschmidt, and others.

Arustamoff, in 1891, observed eleven cases of fish poisoning, five of which proved fatal. The imperfectly salted fish contained enormous numbers of bacteria which formed typhoid-like colonies. The symptoms were general weakness, dull pain in the abdomen, dyspnea, mydriasis, vertigo, and dryness of the mouth. It is probable that diseased fish were packed away with wholesome ones and, as a result, the entire mass became eventually infected. Cooking destroyed the toxicity of the fish.

The more recent work of Konstansoff (1904) threw additional light upon the nature and cause of fish poison. A salted sturgeon which poisoned two people was examined by him and found to be sterile. The sterility was due to the presence of 15.6 per cent. salt. Although free from organisms, a powerful soluble toxin, resembling in its action that of *B. botulinus* was extracted from the fish. Evidently, the salting had put an end to a partial decomposition but while it destroyed the organisms present it was without effect on the already elaborated toxin.

Schmidt believed the fish poison to be an animal alkaloid, a ptomain, produced most probably by bacteria that cause an infectious disease in the fish. Anrep partially isolated two active ptomains from poisonous fish. One of these was extracted from alkaline solution with ether, chloroform, and benzin. It was fatal to rabbits in doses of 0.5 milligram. A somewhat similar ptomain was isolated by Kakolew. From our present knowledge of bacterial poisons it is quite certain that the real toxic principle in poisonous fish, like that of *Bacillus botulinus*, of tetanus or of diphtheria, is not a basic product but is rather a toxin.

It is clear therefore that the ordinary fish poisoning is due to bacterial invasion of the fish, either during life or after death. The organisms concerned may be of the most varied kind, sometimes cocci, more often bacilli. Among the latter should be mentioned those of the Colon and Proteus group. The *B. enteritidis* and *B. paratyphosus B*, common in meat poisonings, have also of recent years been isolated. The presence, at times, of *B. botulinus* or of a similar organism is indicated in those poisonings where symptoms show involvement of the cerebrospinal system.

Ballard reported fatal poisoning following the use of canned salmon. The can was "blown" and the contents were partially decomposed. The one who ate the most was attacked about ten hours after eating and

died in three days. One who ate less became ill in about twelve hours and died in five days, while three others recovered. Klein found in both fatal cases necrosis of the mucous membrane of the stomach, fatty degeneration of the liver, and inflammation of the kidneys. Mice fed upon the salmon died, but no germs could be found in their blood. Evidently, as in Van Ermengem's case, a powerful toxin was produced by a mere saprophytic organism.

Another instance of poisoning from canned salmon is that reported by Vaughan. In this case the patient suffered from nausea, vomiting, and a griping pain in the abdomen; six hours later he vomited at frequent intervals small quantities of bile-colored mucus. Constipation was present and a scarlatinous rash appeared, covering the body from head to foot. The pulse was 140 and the temperature 102° F. Although the rash disappeared next day, a slight fever persisted for some time and the patient was confined to his house for a week. From the salmon Vaughan isolated a micrococcus which proved highly toxic when grown under anaërobic conditions.

Poisonous Milk.—Milk is unquestionably a most prolific source of intoxication and especially of real infection. This is readily understood when it is remembered that raw milk, the form in which it is most often consumed, contains enormous numbers of bacteria. Under most exceptional conditions a disease of the animal may be transferred through the milk which it secretes. As a rule, however, large numbers of bacteria from all imaginable sources enter the milk after it leaves the animal. More or less fermentation, even if no change is recognizable by the eye or taste, exists necessarily in such a product. The diarrheas of infancy only too often stand in the same relation to milk as do the forms of gastroenteritis resulting from the use of infected meats. Again, the transmission of typhoid fever through milk is known to have occurred. Thus Davies, in 1897, reported an outbreak of 197 cases of typhoid fever, all of which were directly traceable to one milk supply. Wilckens, in 1898, reported upon a similar epidemic which developed in Hamburg. Of the 82 cases unquestionably resulting from milk infection 65 were in women and children and only 17 were in men. Instances of this kind could be multiplied not only as regards typhoid fever but also as to other infectious diseases, notably streptococcal sore throat. However, by milk poisoning, or galactotoxismus, usually is meant acute intoxications analogous to those noted in connection with meat and fish.

The *tyrotoxicon*, discovered by Vaughan in 1885, first in cheese and later in milk, has been repeatedly found in milk and other milk products since then. Newton and Wallace in 1886 reported an outbreak of milk poisoning of this kind which affected a large number of people at Long Branch. In the same year Schearer found tyrotoxicon in milk used by, and in the vomited matter of, persons made sick at a hotel in Corning, Iowa. In 1887 Firth, an English army surgeon stationed in India, reported an outbreak of milk poisoning among the soldiers of his garrison, and from the milk he isolated tyrotoxicon. In the same year Vaughan reported an instance of milk poisoning, due to tyrotoxicon, in which three of the patients died. In 1898, Wesener and Rossmann reported the isolation of tyrotoxicon in crystalline form from poisonous cheese. The exact nature of this substance has never been established.

In view of the large number of different species of bacteria which may be present in milk it is evident that diverse organisms may take the causative rôle and hence different toxins may be elaborated in milk. Gaffky, for example, reports an instance in which three laboratory men became infected through milk, and suggests that the epidemic which prevailed in Christiania in 1888, in which 6,000 people sickened within three weeks, was probably due to milk infection. From the former instance Gaffky isolated a small, highly virulent form of the colon bacillus.

Poisonings from various products of milk such as ice-cream, cream-puffs, and frozen custards have been frequently met with. In such cases undoubtedly the injurious organism is derived from the milk and with favorable conditions is enabled to multiply and give rise to its peculiar toxin. Here again no one organism is at work in all poisonings of this kind and consequently diverse poisons are to be expected. Coloring matter and especially flavoring extracts, such as vanillin, are often credited with causing these poisonings, but it can be readily shown that large quantities of such extracts can be taken without the least injury. While it is possible for deleterious substances or poisonous metals to find their way into milk, ice-cream, and other products, yet such instances have not been demonstrated. On the contrary a careful examination of such poisonous matter will invariably demonstrate the presence of toxic bacteria and their products.

In poisonous ice-cream, Vaughan and Novy repeatedly found tyrotoxicon, and this toxic bacterial product has been likewise detected in similar material by Schearer, Allaben, and Welford. In 1896, Vaughan and Perkins reported upon an outbreak of ice-cream poisoning which affected many people. Nausea, vomiting, and diarrhea were as a rule present and the most alarming feature was the feebleness in the heart's action. In some persons the entire body became cool and clammy and the radial pulse was not detectable. In some delirium and stupor were also present. The germ isolated from the ice-cream showed a marked resemblance to the colon bacillus.

Cheese poisoning, or tyrotoxismus, like sausage poisoning, is of relatively frequent occurrence and for that reason both attracted the attention of scientists at an early date. It is unnecessary to recapitulate the various theories that have been propounded from time to time to account for this toxicity of cheese. The phenomenon is readily explained along the lines heretofore laid down. Various toxicogenic bacteria may accidentally develop during the ripening or storage of the cheese and consequently impart to it poisonous properties. To Vaughan is due the credit of being the first to discover and isolate the chemical poison tyrotoxicon, in several outbreaks of cheese poisoning. Wallace, Wolff, and others have also isolated the same poison from cheese. Dokkum, employing a modification of the method used by Vaughan, isolated a somewhat different substance to which he gave the name tyrotoxin. From poisonous cheese Le Pierre obtained a basic body, $C_{16}H_{23}N_2O^4$. Insufficient attention has been given in the past to the study of the bacteria present in toxic cheese, and it is to be hoped that in the future special attention will be directed to this work. The studies of Vaughan and McClymonds have shown that toxicogenic germs are present in nearly all cheese. Cultures obtained from forty-nine samples of American green cheese killed white rats, guinea-pigs, and rabbits. The colon group is usually thus represented, and it is therefore a matter of little surprise if under favoring conditions some of these organisms develop sufficiently to render a given sample poisonous.

Poisonous Molluscs.—Mussel poisoning, or mytilotoxismus, is characterized by a greater variety of symptoms and a relatively greater fatality than is observed in other food infections. There can be no question as to the main fact that poisonous mussels owe their toxicity to the presence of bacteria and more especially to the products elaborated by these organisms. It is possible, however, as Boinet (1911) pointed out, that isolated cases of mussel poisoning may be of the nature of anaphylactic intoxications.

In general three types of symptoms have been noted. A gastroenteritis, characterized by nausea, vomiting, and diarrhea, shows no difference from many of the

common instances of meat poisoning. The exanthemic type has been most frequently observed. This begins with a sensation of heat which spreads from the face to all parts of the body and is followed by a papular or vesicular eruption. Itching is a marked feature and dyspnea may be pronounced. The third type is very similar to that observed by Van Ermengem in connection with the *Bacillus botulinus* which he isolated from ham. The symptoms on the part of the nervous system predominate. Headache, dizziness, constriction of the throat, difficulty in speech, extreme muscular weakness, and numbness and coldness of the limbs are marked symptoms. The pupils are dilated and reactionless, but the pulse is relatively low and there is no elevation of temperature.

One of the best studied outbreaks of mussel poisoning was that of Wilhelmshaven. In this case the cooked mussels produced symptoms within an hour or more and death resulted in two, three, and five hours after eating. From these mussels Brieger obtained the highly poisonous ptomain *mytilotoxin*. The fact that the poisonous mussel were obtained from brackish water and that they became non-poisonous when removed to fresh sea-water would indicate that the mussel were either diseased or their vitality was lowered to such an extent that they allowed the free development of toxicogenic bacteria.

Instances of poisoning with oysters are frequent enough. This is especially true when the oysters come from a bed polluted with sewage. Just as polluted milk or water may be the carrier of typhoid fever, so likewise oysters when gathered from polluted banks can, and have been known to, cause epidemics of this disease as well as less dangerous diarrheas. At times the symptoms of acute intoxication following the use of oysters are as pronounced and as fatal as those noted in connection with mussel poisoning. Brosch, for example, reported a case in 1896 in which an officer died in twelve hours after eating some oysters which at the time were noted to have a bad taste. The symptoms were of the paralytic type: dimness of vision, salivation with inability to swallow or expectorate, anuria, difficult and indistinct speech, with paralysis of the right side of the face, including dilatation of the pupil and ptosis of the right eyelid, great muscular weakness, cyanosis and death.

Poisonous Vegetable Foods.—Although animal foods are most often the cause of food poisoning, yet they are by no means alone in this respect. Canned vegetable foods, tomatoes for example, have been known to give rise to serious illness. The presence of toxicogenic bacteria or of their products is responsible for these effects rather than are the traces of tin or lead which may be present. Instances of slimy bread which, as is well known, are due to the presence of slime-producing bacteria of the potato bacillus group, have been shown by Vogel to cause at times marked symptoms of gastroenteritis.

The most severe form of food poisoning, that due to B. botulinus, has also been observed in connection with vegetable foods. Thus, a notable instance occurred in Darmstadt, in 1904, where canned beans produced fatal illness in eleven out of twenty-one cases. The symptoms were identical with those of botulismus caused by meat, and from the material Landmann isolated the above-named organism.

An even more striking example was reported by Peck (1910) from Sawtelle, Cal., where eleven out of twelve persons died after eating canned pears. While in this case the organism was not isolated, there can be no doubt but that it was one of true botulism.

During recent years poisonings have been reported from puddings, gruel, oat-meal, beans, noodles, potato salad, etc. The organisms found in these outbreaks were usually *B. enteritidis*, or *B. paratyphosus* B. though *B. coli*, *Proteus vulgaris*, and even the hay bacillus have been isolated from some of this material.

Under the designation *siitotoxismus* Vaughan includes all forms of poisonings with vegetable foods, infected with moulds and bacteria. Mould infections especially play a most important part in vegetable foods, whereas they are practically unknown in connection with food of animal origin. The best-known example of this kind is ergotismus, veritable epidemics of which have prevailed in different parts of Europe during past centuries. At present, examples of this form of intoxication are relatively rare and are practically unknown in this country. The cause is the fungus, Claviceps purpurea, which develops on rye and other grain. At least three poisons, ergotinic acid, sphacelinic acid, and cornutin, were formerly looked upon as the active constituents of ergot. Since 1907, Barger and Dale have isolated three important toxic agents from ergot, namely—ergotoxine, parahydroxyphenyl ethylamine and β-iminazolyl ethylamine. Another compound found in ergot extracts is agmatine. The three last mentioned are derived by the splitting off of carbonic acid from tyrosine, histidine, and arginine, respectively. The inert amino acids become converted thus into toxic compounds.

The disease known as pellagra, which prevails to an unfortunate extent in Southern Europe and even in this country was formerly considered to be due to the eating of spoiled corn. Recent studies, however, have discredited this view and the etiology is still a matter of investigation.

Examination of Poisonous Foods.—A description of the various kinds of food poisonings would be incomplete without some statement of the methods to be pursued in making examinations of suspected material. It not infrequently happens that the amount of food that is left over from a meal is very small and for that reason it should be put to the best possible use. Inasmuch as a chemical analysis is of very little value it is not advisable to use up the greater part of the material in such work. At all events it should be deferred until a complete bacteriological examination has been made. The chemical substances will in no wise suffer by such delay.

A considerable amount of time can be saved, and perhaps wrong conclusions avoided, by determining at the outset whether or not the suspected food is really poisonous. This is apparently a simple proposition but not always one that can be easily carried out. Some animals are not susceptible to a given poisonous food, while others are. Consequently, as many different animals as possible should be fed or given, through a stomach tube, the material under investigation until some are found to be susceptible. In comparatively mild poisonings the experimenter has been known to make the crucial test on himself.

In the case of pork and its products the presence or absence of trichinæ should be determined at the outset. In case the poisonous nature of the food is established by feeding experiments the affected or dead animals may be examined by the usual methods for bacteria. It should be remembered, however, that there are cases in which no bacteria can be detected in the dead body, for the reason that they may be unable to multiply in the living body, although they may elaborate powerful poisons in the food itself. Death in such instances would be the result of a true intoxication. On the other hand, the poisonous organism may grow in the body and an infection proper may result, in which case the germ will be found distributed through the body.

The feeding experiments should be supplemented by injections, subcutaneous and intraperitoneal, of macerations of the food in sterile water. Eventually, aërobic and anaërobic cultures should be made with the poisonous food and the toxic organism should be isolated and its effects, in pure culture, studied upon susceptible animals. The selective media employed

for the detection of typhoid and paratyphoid bacilli should be used in this work, and the serum reactions should not be overlooked. The presence of soluble poisonous products in such cultures may be demonstrated by filtration through porcelain.

FREDERICK G. NOVY.

Foods for the Sick.—The proper adjustment of food for the individual in health yields results, in the form of work and physical well-being, that will fully reward the dietetic care exercised. Man has at his disposal a greater variety of foods than any other animal. The methods pursued in the preparation of the food will greatly modify its taste and digestibility.

A *food* is any substance which can be utilized in the living organism for structural or functional purposes.

A *complete food* must contain all of the substances necessary to construct and maintain the activities of the tissues of the body. Thus, while meat furnishes us food in concentrated form, it is a simple and not a complete food. Milk is composed of the elements necessary to construct and maintain the human economy. Such a food must contain water, mineral matter, nitrogenous matter, carbohydrates, and fats. It is not enough that a substance possess these elements in order to be regarded as a complete food, but it must possess them in assimilable form and of such a character that sufficient for nutritive purposes may be ingested.

The individual in health gives little heed to proper combinations of food elements and the intake of nourishment sufficient to secure a condition of nutritional equilibrium. It is only when the viscera concerned with the elaboration and utilization of food have been disordered by disease or the ingestion of an excess, or of unsuitable food, that dietetic measures are considered.

The problem of adjusting the food to the requirements of the individual in health is most complex; the adaptation of the dietary to diseased organs is yet more complicated.

FACTORS CONCERNED IN THE SELECTION OF FOOD FOR THE SICK.—The calorie values of the various foods are being given more extended consideration in our ordering of food for the sick. It is too soon to expect them to form the sole basis of the dietary except in selected cases, *e.g.* typhoid fever, diabetes, and infant feeding. They have already furnished the data to discredit the limited dietary of typhoid fever. That ordinary "beef tea has starved more people than were killed by Napoleon's wars," is a familiar saying. The same may be observed of the customary three pints of milk allowed a typhoid fever patient. A study of calorie values seems to be the best way to impress the important lesson of treatment so generally disregarded, namely, that drugs can influence force only after it has been generated either by a sufficient food intake or by the consumption of the food elements comprising the body; or again, that a sufficiency of the calorie value of the diet may not be disregarded save in illness of brief duration.

The adjustment of the diet of the sick has been subject to marked changes in the recent past as a result of the fuller understanding of the problems concerned with digestion and metabolism and the better understanding of the requirements of the economy in health and as influenced by various morbid processes.

TABLE OF LIQUID AND SEMI-LIQUID DIET IN CALORIES AND PORTIONS. (DR. C. B. FARR.)

Description of articles.	Description of portions.						
	Rough measure.	Exact measure.		Protein, grams.	Fat, grams.	Carbohydrate, grams.	Calories.
		Grams.	Oz. av.				
Milk, whole (4 per cent. fat)	A glassful or 7 fluid ounces	217	7.6	7.1	8.7	10.8	150
Milk, skimmed (0.3 per cent. fat)	A glassful or 6⅞ fluid ounces	205	7.2	7.0	0.6	10.4	75
Buttermilk (0.5 per cent. fat)	A glassful or 6¾ fluid ounces	210	7.4	6.3	1.1	10.0	75
Whey (0.3 per cent. fat)	A glassful ("scant") or 6 fluid ounces	187	6.6	1.9	0.6	9.4	50
Cream (18.5 per cent. fat)	1½ tablespoonfuls or ⅝ fluid ounce	26	0.9	0.6	4.8	1.1	50
Butter (85 per cent. fat)	1 teaspoonful (rounded)	7	0.2	0.1	5.5	0.0	50
Sugar (granulated cane—powdered milk, malt, etc.).	2 teaspoonfuls (rounded) of granulated, 1 tablespoonful (heaping) of powdered.	13	0.4	0.0	0.0	12.5	50
* Oat or barley gruel (1 oz. of the flour to quart of water).	A glassful or 7 fluid ounces	218	7.6	1.0	0.0	5.2	25
* Legume gruel (1 oz. of the flour to quart of water).	A glassful or 7 fluid ounces	217	7.6	1.7	0.0	4.6	25
Soda crackers (for use with milk)	One cracker	6	0.2	0.6	0.5	4.4	25
Toast dried in oven (for use with milk).	1 thick (3 in. × 3 in. × ½ in.) or 2 thin slices (wt. as bread: 39 grams).	23	0.8	3.6	0.5	20.4	100
Egg	One average (weight includes shell)	57	2.0	6.8	5.3	0.0	75
White of egg (in glass of water, lemonade, or beef extract).	Two average "whites"	49	1.7	6.0	0.1	0.0	25
* Beef juice (pressed—Holt)	Two tablespoonfuls	40	1.4	2.0	0.2	0.0	10
* Beef broth (Holt), mutton and chicken similar).	Large cup or 8 fluid ounces	250	8.8	2.5	trace	0.0	10
Olive oil (or cottonseed oil)	One tablespoonful (even), ⅝ fluid ounce	11	0.4	0.0	11.1	0.0	100
Gelatin (1 pckge. gelatin, ½ lb. sugar, 2 qts. water).	7 tablespoonfuls or 3½ fluid ounces	100	3.5	1.8	0.0	11.0	50
Junket (1 qt. milk, 2 oz. sugar)	8 tablespoonfuls or 4 fluid ounces	110	3.9	3.6	4.4	11.7	100
Soft custard (same with 4 eggs)	5 tablespoonfuls or 2½ fluid ounces	83	2.9	5.0	5.1	8.8	100
Corn starch (1 qt. milk, 2 oz. sugar, 1 oz. of corn starch).	7 tablespoonfuls or 3½ fluid ounces	100	3.5	3.3	4.0	13.0	100
Rice pudding (1 qt. milk, 2 oz. sugar, 3 oz. of rice.	6 tablespoonfuls or 3 fluid ounces	83	2.9	3.3	3.3	14.4	100

Data derived directly or indirectly from Bull. 28 Dept. Agriculture (*exceptions).

TABLE SHOWING THE NUTRITIVE VALUE OF THE FOOD MATERIALS CALCULATED FOR THE QUANTITIES COMMONLY REQUIRED FOR COOKING SMALL PORTIONS.

(FROM PRACTICAL DIETETICS BY ALIDA F. PATTEE.)

Food material (uncooked).	Measure.	Weight.		Protein.	Fat.	Carbohydrate.	Fuel value.
		Ozs.	Gms.	Gms.	Gms.	Gms.	Calories
A							
Almonds, shelled	1 cup	5.6	160	33.6	87.8	27.7	1035
Apples, fresh	1 medium	5 +	150	0.5	0.5	16	70
Apples, dried	1 cup	3	85	1.4	1.8	56.2	247
Apricots, dried	1 cup	5	142	6.6	1.4	88.5	354
Arrowroot	1 tablespoon	½	14+			13.8	55
Asparagus	1 bunch	44 (2¾ lbs.)	1247	22.4	2.4	41.0	276
B							
Bacon	1 serving.	0.6	18	1.6	10.4		100
Bacon	1 lb.	16	454	43	269.4		2597
Bananas	1 medium	3½	100	0.8	0.4	14.0	64
Barley, pearl	1 tablespoon	1	27	2.2	0.3	19.8	90
Barley, crushed	1 tablespoon	½	14+	1.1	0.1	11.3	51
Barley, flour	1 tablespoon	½+	16	1.3	0.2	12.5	57
Barley, flour	1 cup	8	227	19.0	2.5	174.3	799
Bass (edible portion)	1 serving.	3½	100	18.6	2.8		100
Bass (edible portion)	1 lb.	16	454	84.3	12.6		452
Beans, string	1 serving	4	113	2.4	0.3	5.8	44
Beef broth	1 serving.	3½	100	10.3	0.3		44
Beef broth	1 quart	32	907	93.4	2.7		398
Beef juice	1 serving.	3½	100	4.9	0.6		25
Beef marrow	1 tablespoon	½	14.1	0.31	13.1		120
Beef marrow	1 lb.	16	454	9.92	420.8		3828
Beef steak, porterhouse	1 serving.	3½	100	19.1	18.0		238
Beef steak, porterhouse	1 lb.	16	454	86.6	81.2		1077
Beef steak, rump	1 serving.	3½	100	21.0	13.7		207
Beef steak, rump	1 lb.	16	454	94.8	62.1		938
Beef steak, sirloin	1 serving.	3½	100	16.5	16.1		211
Beef steak, sirloin	1 lb.	16	454	74.8	73.0		957
Beef steak, top of round	1 serving.	3½	100	19.5	7.3		144
Beef steak, top of round	1 lb.	16	454	88.45	33.1		652
Blue fish (edible portion)	1 serving.	3½	100	19.4	1.2		88
Blue fish (edible portion)	1 lb.	16	454	87.8	5.44		401
Brandy	1 tbsp.	½	14+				42
Bran	1 cup	2½	71	7.8	1.5	43.4	218
Brazil nuts, shelled	1 lb.	16	454	76.94	302.88	31.68	3048
Brazil nuts, shelled	1 nut	¼		1.20	4.74	0.05	47.6
Brazil nuts, shelled and chopped	1 tablespoon	¾		3.6	14.22	0.15	142.8
Bread, white	1 slice	1	28.4	2.6	0.3	15.0	73
Bread, white	1 loaf	12	340	31.6	4.1	179.3	881
Bread, crumbs (dry)	1 cup	4⅔	136	12.6	1.6	71.7	352
Bread, Boston brown	1 small slice.	1	28.4	1.5	0.5	13.3	64
Bread, gum gluten	1 slice	1	28.4	8.4	0.30	8.5	70.3
Bread, gum gluten	1 loaf	13	386.5	114	4	116.3	957.2
Butter	1 tablespoon	½	14+	0.1	12.1		109
Butter	1 cup	8	227	2.2	193		1744
C							
Carrots	1 small.	2.0	57	0.5		4.2	20
Cauliflower	1 serving.	4.0	113	2.0	0.6	5.2	35
Celery	1 serving.	2.0	57			1.4	6
Cheese, American	1 tablespoon	½	15	4.0	5.0		62
Cheese, American (fresh grated)	2 tablespoon	1	28.4	8.0	10.0		124
Cheese, cottage	1 serving.	1	28	5.9	0.28	1.2	31
Cheese, cream	2 tablespoon (1½ cubic inch)	8	23	6.1	8.1	0.5	100
Chicken (edible portion)	1 serving	3½	100	21.4	2.5		108
Chicken	1 lb.	16	454	97.5	11.3		492
Chocolate (unsweetened)	1 square	1	28.4	3.65	13.8	8.59	173
Chocolate (unsweetened)	1 lb.	16	454	58.5	220.9	137.4	2772

TABLE SHOWING THE NUTRITIVE VALUE OF THE FOOD MATERIALS CALCULATED FOR THE QUANTITIES COMMONLY REQUIRED IN COOKING SMALL PORTIONS.—(*Continued.*)

Food material (uncooked).	Measure.	Weight.		Protein.	Fat.	Carbohydrates.	Fuel value.
C —(*Continued*)		Ozs.	Gms.	Gms.	Gms.	Gms.	Calories
Clams (edible portion)	1 serving.	3½	100	8.6	1.0	2.0	51
Clam bouillon.	1 serving.	3½	100	0.2		0.2	2
Clam bouillon.	1 quart.	32	906	2.0	0.8	1.6	23
Claret (10% alcohol)	1 tablespoon.	½	14				10
Cocoa	1 tablespoon.	¼	7+	3.0	4.1	5.3	70
Cod, fresh (edible portion)	1 serving.	3½	100	16.5	0.4		76
Cod, fresh	1 lb.	16	454	74.8	1.8		315
Cod fish, salt, boneless	1 serving	2	57	15.7	0.2		64
Cod fish, salt, boneless	1 lb.	16	454	125.6	1.4		515
Condensed milk, Eagle brand	1 teaspoon.	0.388	11	0.88	1.057	6.07	38.25
Condensed milk, Eagle brand		1	28.35	2.77	2.72	15.66	98.59
Condensed milk, Eagle brand	1 can.	16	450	36.33	43.79	250.60	1579.33
Consomme	1 serving.	3½	100	2.5		0.4	12
Consomme	1 quart.	32	906	10.0		1.6	46
Corn	1 cup.	10	28.4	7.9	3.4	53.9	278
Cornmeal	1 tablespoon.	½	10	0.8	0.2	7.1	34
Cornmeal	1 cup.	5	142	13.0	2.6	106.8	504
Cornstarch	1 tablespoon.	½	10			9.5	38
Cornstarch	1 cup.	5½	156			197.4	790
Cracker crumbs	1 cup.	5+	151	16.5	9.0	110.2	588
Crackers, water	1 large.	½	10	1.2	0.5	7.6	40
Cream, thin (18%)	1 tablespoon.	½	14	0.4	2.8	0.7	29
Cream, thin (18%)	1 cup.	8	227	5.6	41.9	10.2	440
Cream, thick (40%)	1 tablespoon.	½	14	0.3	6.0	0.5	57
Cream, thick (40%)	1 cup.	8	227	4.99	90.7	6.8	864
Cucumbers, fresh (edible portion)		1	28.4	0.23	0.6	0.89	5
Currants, fresh	1 cup.	5	142	2.12		18	81
Currants, dried	1 cup.	8	227	5.44	3.84	84	728
D							
Dates (with stones)	1 cup.	8	227	4.0	5.6	160.8	710
Dry peptonoids, soluble	1 tablespoon.	2	159	6		8	57
E							
Eggs, whole, average size (without shell)	1	1½	45	5.4	4.2		60
Eggs, white	1	1/10	25	3.3			13
Eggs, yolk	1	½	13	2.1	4.5		48
F							
Farina	1 tablespoon.	½	10	1.0	0.1	7.2	34
Farina	1 cup.	6	170	18.7	2.3	129.8	616
Figs	1 fig.	1	28.4	1.3	0.1	22.2	95
Figs	½ lb.	8	227	9.7	0.7	168.2	718
Filberts, shelled	1 lb.	16	454	70.72	296.16	58.88	3184
Filberts, shelled	1 doz.	¾		3.3	13.89	2.76	150
Filberts, shelled	1 tablespoon.	½		2.21	9.26	1.84	100
Flour, barley	1 tablespoon.	½+	16	1.3	0.2	12.5	57
Flour, barley	1 cup.	8	227	19.0	2.5	174.3	796
Flour, gum gluten	1 tablespoon.	½	8	3.46	0.12	3.48	29
Flour, gum gluten	1 cup.	5	142	60	2.3	63	512.7
Flour, Graham	1 tablespoon.	½	8	1.3	0.2	6.8	34
Flour, Graham	1 cup.	5	142	18.8	3.2	101.2	509
Flour, rice	1 tablespoon.	½	16	1.4	0.04	10.2	58
Flour, rice	1 cup.	8½	241	18.9	0.7	187.8	870
Flour, rye	1 tablespoon.	½	8	0.5	0.07	6.3	28
Flour, rye	1 cup.	5	142	0.6	1.3	111.5	496
Flour, wheat (roller process)	1 tablespoon.	½	8	0.9	0.08	6.0	28
Flour, wheat (roller process)	1 cup.	5	142	15.9	1.4	106.2	500
Fowl (edible portion)	1 serving.	3½	100	19.3	16.3		224
Fowl (edible portion)	1 lb.	16	454	87.5	73.9		1015

Table Showing the Nutritive Value of the Food Materials Calculated for the Quantities Commonly Required in Cooking Standard Portions.—(Continued.)

Food material (uncooked).	Measure.	Weight		Protein.	Fat	Carbohydrates	Fuel value
		Ozs.	Gms.	Gms.	Gms.	Gms.	Calories
G							
Gelatin, granulated	1 tablespoon.	1/6	8.5	7.8			31
Gelatin granulated	1 box	1 1/6	34	31.1			125
Gelatin, shredded	1/2 box	3/8	17	15.6			62
Gum gluten flour	1 tablespoon.	1/4	8	3.46	0.12	3.48	29
Gum gluten flour	1 cup.	5	142	60	2.3	63	512.7
Gum gluten flour	1 lb.	16	450	191	7.3	200	1629.7
Gum gluten bread	1 slice	1	28.4	8.4	0.30	8.5	70.3
Gum gluten bread	1 biscuit	13	386.5	114	4	116.3	957.2
Gum gluten biscuit crisp	1 loaf	1/4	7	2.94	0.13	3.15	25.5
Gum gluten noodles	1 cup	3 1/2	100	45	4.2	32.5	350
Greens	1 serving	4	113	2.3	0.3	3.6	27
Grapes, Malaga	1 dozen	2	57	0.74	0.9	10.88	55
Grapes, Malaga	1 lb.	16	454	4.5	5.4	65.3	328
Grape juice	1 tablespoon.	1/2	14			3.8	15
Grape juice	1 cup	8	227			60.0	240
H							
Haddock (edible portion)	1 serving	3 1/2	100	17.2	0.3		72
Haddock (edible portion)	1 lb.	16	454	77.9	1.36		324
Halibut (edible portion)	1 serving	3 1/2	100	18.6	5.2		121
Halibut (edible portion)	1 lb.	16	454	84.3	23.5		549
Ham, fresh, lean	1 serving	3 1/2	100	24.8	14.2		227
Ham, fresh, lean	1 lb.	16	454	112.6	64.4		1029
Hickory nuts, shelled	1 lb.	16	454	69.76	305.6	51.68	3234
Hickory nuts, shelled and chopped	1/4 cup	1 1/2		6.54	28.5	4.83	303
Hickory nuts, shelled and chopped	1 tablespoon.	1/2		2.18	9.5	1.61	101
Hominy	1 tablespoon.	1/2	14	1.2	0.1	11.2	50
Hominy	1 cup	8	227	18.9	1.4	179.2	805
Honey	1 tablespoon.	1	28.35	0.133		23.02	92.5
J							
Jell-O	1 box	3.5	100	11.2		86.4	395
Jell-O	1 serving	0.6	16	1.9		14.4	6
K							
Kumyss	1 qt.	34.4	975	2.2	2.1	1.5	328
L							
Lamb chops	1 serving	3 1/2	100	18.7	28.3		329
Lamb chops	1 lb.	16	454	84.8	128.3		1494
Lard	1 tablespoon.	0.5	14		14		127
Lard	1 lb.	16	454		484		4083
Lemon juice (1 lemon)	3 tablespoon.	1 1/2	42			4.2	17
Lettuce	1 head	8	227	2.3	0.5	5.7	36
Liquid Peptonoids	1 tablespoon.	1/2	15	0.8		2.1	28
Lobster (edible portion)	1 serving	3 1/2	100	18.1	1.1	.5	84
Lobster (edible portion)	1 lb.	16	454	82.08	4.96	2.24	382
M							
Macaroni	1 cup	3 1/5	108	14.7	1.0	81.1	392
Mackerel, fresh (edible portion)	1 serving	3 1/2	100	18.7	7.1		139
Mackerel, fresh (edible portion)	1 lb.	16	454	84.8	32.16		629
Mackerel, salted	1 serving	3 1/2	100	16.3	17.4		222
Mackerel, salted	1 lb.	16	454	73.9	78.9		1007
Malted milk, Horlick's	1 tablespoon.	1/2	14	2.3	1.2	9.5	59.54
Milk, whole	1 tablespoon.	0.7	20	0.066	0.8	1.0	14
Milk, whole	1 cup	8.6	244	8.0	9.3	12.2	169
Milk, whole	1 quart	34.4	975	32.2	39.0	48.8	675

Table Showing the Nutritive Value of the Food Materials Calculated for the Quantities Commonly Required in Cooking Small Portions.—(*Continued*)

Food material (uncooked).	Measure.	Weight.		Protein.	Fat.	Carbohydrates.	Fuel value.
M—(*Continued*)		Ozs.	Gms.	Gms.	Gms.	Gms.	Calories.
Milk, skimmed	1 tablespoon	0.7	20	0.7	0.06	1.0	7
Milk, skimmed	1 cup	8.6	244	8.3	0.7	12.5	89
Milk, skimmed	1 quart	34.4	975	33.1	2.9	49.7	358
Molasses	1 tablespoon	⅘	27	0.6	.....	18.7	77
Molasses	1 cup	11	317	7.6	.....	219.7	909
Mutton chops	1 serving	3½	100	16.0	33.1		362
Mutton chops	1 lb	16	454	72.5	150.1		1640
N							
Noodles, gluten	1 cup	3½	100	45	4.2	32.5	434
O							
Oatmeal, granulated	1 tablespoon	½	14+	1.8	0.9	9.9	55
Oatmeal, granulated	1 cup	8	227	28.8	14.7	158.2	880
Oats, rolled	1 tablespoon	⅕	5	0.7	0.3	2.7	16
Oats, rolled	1 cup	2½	71	11.8	5.2	46.9	282
Olive oil, Nicelle	1 tablespoon	½	15	.....	15	.....	135
Olives	2 or 3	0.5	14	0.1	2.8	1.2	31
Onion	1 serving	4	113	1.8	0.3	11.2	56
Orange	1 medium	5	142	1.2	0.3	17.4	77
Orange juice	1 tablespoon	½	14	.....	.....	1.6	6
Orange juice	1 cup	8	227	.....	.....	25.6	104
Oysters	2	1	28.4	1.7	0.3	1.0	14
Oysters	1 cup (solid	6	170	10.5	2.0	6.3	84
P							
Panopepton	1 tablespoon	½	15	1	.....	2.5	30
Peaches, fresh	1 medium	4	113	0.8	.1	11.3	50
Peaches, dried	1 cup	3	85	1.4	1.8	56.2	247
Peach juice	1 tablespoon	½	14	.....	.....	1.1	5
Peach juice	1 cup	8	227	.....	.....	17.6	80
Peanuts, shelled	1 cup	5	142	36.55	54.7	34.55	777
Peanut butter	1 tablespoon	0.6	16	4.8	7.7	2.8	100
Peas, green	1 serving	4	113	7.7	0.5	19.6	114
Peas, canned	1 cup	6½	184	6.6	0.4	18.0	100
Pecans, shelled	1 cup	5.5	156	15.0	110.0	23.8	1145
Pineapple, fresh (edible portion)		8	227	0.9	0.7	22	98
Pineapple, canned	1 slice	3	85	0.4	0.6	31	130.5
Pineapple, canned	1 cup	8	227	0.9	1.6	82.6	1348
Pineapple, canned	1 can	24	680	2.6	4.8	247	044
Port wine (10% alcohol)	1 tablespoon	½	15	.....	.....	.....	10
Potatoes, white	1 medium	3½	100	2.2	0.1	18.4	83
Potatoes, sweet	1 medium	3½	100	1.8	0.7	27.4	123
Prunes	1 cup	5	142	2.5	.....	88.1	363
Prunes	3 prunes	1	28.4	0.5	.....	17.6	72
Q							
Quail	1 serving	3½	100	21.8	8.0	.....	159
R							
Raisins	1 dozen	½	9	0.2	0.3	6.5	29
Raisins	1 cup	4	113	2.6	3.4	77.6	352
Raspberries, fresh, black (edible portion)	1 cup	5	142	2.4	1.4	17.8	94
Raspberry juice	1 cup	8	227	.....	.....	22.6	90
Rhubarb		1	28.4	0.2	0.2	1.0	6
Rhubarb		16	454	2.7	3.2	16.3	105
Rice	1 tablespoon	½	15	1.1	0.04	11.2	50
Rice	1 cup	8½	240	18.1	0.7	179.1	795
Rum	1 tablespoon	½	14	.....	.....	.....	38

Table Showing the Nutritive Value of the Food Materials Calculated for the Quantities Commonly Required for Ordinary Portions.—(Continued.)

Food material (uncooked.)	Measure.	Weight.		Protein.	Fat.	Carbo-	Energy
S		Ozs.	Gms.	Gms.	Gms.	Gms.	Calories.
Salmon (edible portion)	1 serving	3½	100	22	12.8		203
Salmon (edible portion)	1 lb.	16	454	99.6	57.9		922
Saltines	1 wafer	¼	3	0.4	0.5	2.4	15
Sardines, canned	1 serving	3½	100	23	19.7		269
Sardines, canned	1 can	16	454	104.3	89.2		1224
Shad (edible portion)	1 serving	3½	100	18.8	9.5		161
Shad (edible portion)	1 lb	16	454	85.1	43.0		729
Shad roe	1 serving	3½	100	20.9	3.8	26	128
Sherry	1 tablespoon	½	14				13
Spinach	1 serving	4	113	2.3	0.3	3.6	27
Squabs	1 serving	3½	100	16.3	36.2		391
Squash	1 serving	3½	100	1.4	0.5	9	46
Strawberries (edible portion)	1 serving	4	113	1.0	0.7	7.9	42
Strawberries (edible portion)	1 cup	6	170	1.5	1.0	11.9	63
Strawberry juice	1 cup	8	227			11.4	45
Suet	1 tablespoon	½	14	0.66	11.59		107
Suet	1 lb.	16	454	21.28	371.0		3425
Sugar, granulated	1 tablespoon	½+	15			15.0	60
Sugar, granulated	1 cup	7½	210			210	840
Sugar, loaf	1 lump	0.4	7.6			7.6	30
Sugar, loaf	1 cup	6.5	184			184	736
Sugar, powdered	1 tablespoon	½	12			12	48
Sugar, powdered	1 cup	6.5	184			184	736
Sugar of milk Patch's			1			100%	4.1
Sugar of milk Patch's	1 teaspoon (average size)	0.164	5			100%	20.5
Sugar of of milk Patch's	1 tablespoon	0.564	16			100%	65.6
Sweetbreads	1 serving	3½	100	16.8	12.1		176
Sweetbreads	1 lb.	16	454	76.2	54.8		798
Sweetbreads	1 pair (medium size)	8	227	38.1	27.4		399
T							
Tomatoes	1 tablespoon	½+	15	0.2	0.03	0.6	4
Tomatoes	1 cup	8	227	2.7	0.5	9.0	51
Tomatoes	1 medium (whole tomato)	5	142	0.5	0.3	3.0	16
Tapioca, pearled	1 tablespoon	½	14	0.03		12.3	49
Tapioca, pearled	1 cup	6.5	184	0.4		159.5	640
Tapioca, minute tapioca	1 tablespoon	½	14	0.03		12.2	49
Trout (edible) portion	1 serving	3½	100	17.8	10.3		164
Trout (edible) portion	1 lb.	16	454	80.6	46.7		743
Turnip	1 serving	3½	100	1.3	0.2	8.1	39
Turkey (edible portion)	1 serving	3½	100	21.1	22.9		290.5
Turkey (edible portion)	1 lb	16	454	95.7	103.9		1317
W							
Walnuts, English	1 cup	5½	156	25.8	98.8	25.1	093
Walnuts, English	1 meat		1	0.17	0.63	0.16	7
Whey	1 glass	6½	184	1.8	0.5	9.3	50
Whitefish (edible portion)	1 serving	3½	100	22.9	6.5		150
Whitefish (edible portion)	1 lb.	16	454	103.8	29.4		681

The weights assigned to the various measurements in this table have been determined carefully, but are the results of a limited number of experiments, and hence must be regarded as only approximate. The food values are given with sufficient accuracy to be within the limits of error of computations made on average analysis of food stuffs.

The more extended knowledge of the calorie value of the food elements, the chemical composition of the foods, and the insufficiency of many dietaries previously regarded as adequate, are now being recognized.

So, too, the influence of digestion and absorption, the energy required in metabolizing food, the rate and end-products of metabolism, are each in turn being given fuller consideration and more intelligent application.

THE COMPOSITION OF FOODS.

One gram.	Calorie value
Proteins, tissue builders, force and heat producers	4
Fats, force and heat producers	8.9
Carbohydrates, force and heat producers	4
Mineral matter	

Just how much of each of these elements is required cannot be definitely stated. The protein element is the only one absolutely concerned in the constructive and reconstructive needs of the body. There has been an extended discussion as to the proper protein content of a standard diet. It is generally conceded that it should be about 118 grams. Chittenden contends that fifty grams are sufficient. The amount of carbohydrate and fat required is not to be determined by the same considerations that apply to the adjustment of the protein.

A generally accepted standard dietary is composed of protein 118 grams, fat 56 grams, and carbohydrate 500 grams for a man weighing 154 pounds, doing moderate work. There is an element of error which should be kept in mind in ordering a diet intended to yield a definite calorie value. A given food may represent a certain number of calories, but unless it can be digested and absorbed it will not yield them to the economy.

The calorie value of the various foods is usually tabulated in one of the following ways: (*a*) The calorie value of a pound of a food. (*b*) The weight of a food yielding 100 calories. (*c*) The calorie requirement per kilo of body weight under varying conditions of rest, sleep, light and heavy work. (*d*) The calorie value of individual servings or familiar measures of the prepared food, ready to serve. The last mentioned method is the one best adapted to the sick room.

The following figures are those of Rubner which indicate the calorie requirements for an adult weighing 65 kilos:

During rest in bed. .	1,800 calories or 28 calories per kilo.
In repose	2,100 calories or 32 calories per kilo.
In light work	2,300 calories or 33 calories per kilo.
In moderate work . .	2,600 calories or 40 calories per kilo.
In hard work	3,100 calories or 48 calories per kilo.

Tigertedt estimates the food requirements for various classes of labor as follows:

	Calories.
Shoemaker	2,001–2,400
Weaver	2,401–2,700
Carpenter or mason	2,701–3,200
Farm laborer	3,201–4,100
Excavator	4,101–5,000
Lumberman	Over 5,000

The following by Atwater and Benedict show the average requirements of a vigorous young man:

	Calories per hour.
Man sleeping	65
Man sitting at rest	100
Man at light muscular exercise	170
Man at active muscular exercise	290
Man at severe muscular exercise	450
Man at very severe muscular exercise	600

In disease there is frequently an increased need for food, and a lessened ability to digest it. The demand for nourishment will be influenced by the character of the morbid process. Thus there is a wide range of variation in combustion of nutritive material between the individual who is confined to bed with an acute local inflammation, and one who is subject to an acute infectious disease or a chronic suppurative process. The perverted secretions and functional inactivity associated with certain diseases render it impossible to secure the ingestion and metabolism of sufficient nourishment for the production of the heat incident to the disease. The circulating protein, the fat, the muscular tissue, and, finally, the viscera themselves are drawn upon to furnish the needed food elements for the morbidly active combustive process. One has only to look on the feeble, emaciated convalescent from an acute febrile disease, and to contrast his condition with the previously muscular, rounded form, to realize the extent to which the body consumes its own tissues when it is unable to elaborate and annex other forms of food in the necessary quantities. The intake of food is intermittent, while the necessity for nutriment to maintain the increased activity of this vital process is constant. This condition would indicate the desirability of administering nourishment in assimilable form, in small quantities and at frequent intervals, since it is not what we eat but what we digest and assimilate that determines the sufficiency of any dietetic procedure.

The appetite and digestion will usually furnish a sufficiently reliable guide to regulate the character and quantity of food to be taken in health. In disease, with a perversion of the various secretions, it is not prudent to rely upon the patient's desire or disinclination for food.

The administration of food in disease will be determined by our estimate of the ability of the digestive organs to dispose of it. A temporary withholding of food in certain instances of acute disease will be the best dietetic treatment. The administration of what would ordinarily be an excessive quantity of food is advisable in certain chronic suppurative processes attended with fever. Since the digestive juices are influenced by the absence of fever, it is advisable to administer foods requiring the greatest digestive power at that time of the day when the fever is least active.

It is possible still further to adjust the proper administration of food with reference to existing morbid conditions by observing the rule to select the food with regard to the affected part. Thus, in disease which particularly involves the stomach, it would be best to give food whose digestion is accomplished in the intestines, *i.e.* carbohydrates. The converse is equally true. When the intestines are the seat of the morbid process, a food requiring gastric digestion would prove most acceptable. This differentiation is not absolute, and yet it is reasonable and serviceable.

The dietetic treatment of disease may be planned with skill and care, and yet prove inefficacious because of a disregard of two essential factors in the successful administration of food. Dainty service may be given first place. All that can be pictured as implied by the expression will prove helpful in stimulating and aiding digestion. The glass of milk placed beside the spit-cup of the consumptive patient is not novel, neither is it appetizing. The cereal carelessly smeared over the sides and edges of the container and served in a quantity sufficient for a laborer, is seen more often than it should be. The food sent by a cleanly neighbor is appetizing because it is served with the best china and linen, and the question of its selection has not been discussed with the patient.

Equally important is the preparation of the food. Egg albumin if slightly cooked is digested with the greatest facility. If well beaten it offers the digestive juices least resistance in their solvent action. The hard-bolied white of egg is an example of a food difficult of digestion. Roasted beef having a delicious aroma is far more digestible than the same meat when it is hashed and twice cooked. The chop quickly broiled, so that it retains its juices and is turgid, is

more nutritive than the shrivelled and dried, slowly fried or broiled chop from the same cut of the lamb. The method of preparation of vegetables will determine their digestibility and nutritive worth quite as certainly as it does in the case of animal foods Cereals with the starch cells unruptured by the application of heat or—equally difficult of digestion—cooked in hot fat after the starch granules have been exposed to the action of the over-heated fat, are not of much nutritive value. By the application of the proper amount of heat the cellulose element of certain vegetable foods can be made tender and digestible, and their nutritive worth may be secured instead of being lost between the meshes of the cellular fibers.

The ordering of diet will be simplified by keeping in mind the chemical composition of the various foods.

If animal food is to be made a part of the diet, it becomes necessary to select the form deemed suitable to the digestive power and condition of a given case.

If a vegetable food is to be used, it will be necessary to consider the proportion of nitrogenous or albuminous elements contained in it. We should select vegetables belonging to the class of legumes if a large percentage of nitrogenous material is desired.

In certain instances vegetable nitrogeneous material properly prepared will be found better adapted to impaired digestive power than the animal form. If, on the other hand, food rich in carbohydrates and poor in albuminoids is desired, we should order vegetables containing the purer forms of starch, such as potatoes, rice, corn starch, and arrowroot. The green vegetables, being poor in starch and nitrogen and rich in woody fiber and antiscorbutic elements, are selected with reference to the need and ability of the patient to digest this form of food.

Condiments should be used extensively and judiciously, being more important in sickness than in health. Tea, coffee, cocoa, and chocolate are valuable agents, combining as they do food and therapeutic worth.

The method of preparation of the various foods exercises a determining influence upon their utility. It is not enough to select the foods that may be used in a given instance, but detailed directions with reference to the method of preparation must be supplied. A great variety of foods at one meal may prove unsuitable to certain cases, while a meal composed of a sufficient variety of food principles to constitute a complete food may be found to be easily digested. A meal made up of several kinds of meat and one or more legumes is likely to contain an excess of nitrogenous food. It will probably serve best the purpose in view to consider at this time the chief alimentary substances, and some of the ways of administering them, and in this way avoid the necessity for repeating certain statements when directing the employment of these food agents in the dietetic treatment of disease.

Milk.—This food is the chief article of diet in feeding the sick, and by reason of its availability and the likelihood of its being moderately pure, it is relied upon to supply the nutriment required in almost all forms of disease. When we consider how nearly it is *the ideal complete food* for the invalid, it is in order to give thought to all the means at our command to make it acceptable to the patient. There are those who persist in the idea that they are unable to take milk as a food. They point to the vomited curd as an evidence to their inability to digest it. These people must be taught the fact that the milk taken into the stomach always forms a curd as a necessary part of the process of digestion. Then they must be told that we can so modify the milk that the curd formed will be small and easily digested. Other patients will object to the taste and odor of the milk. These objections must be overcome by a knowledge of the ways in which milk can be made acceptable to a patient.

Let us consider the chemical composition of milk and see what constituents may disagree with the patient. Cow's milk has the following composition:

	Per cent.
Protein	3.50
Fat	4
Sugar	5.00
Bacteria	
Salts	0.8
Water	87.2

It is the casein that most frequently taxes the digestion by reason of the size and density of the curd formed. Therefore the question of successfully administering milk in most instances is one of modifying the curd, so that it may be digested with greater facility.

The fat constituent of milk, represented in the cream, is less frequently a disturbing element in the use of milk as an exclusive diet. The indications for reducing the proportion of fat in the milk would be presented by disease or perverted function of the organs concerned in digesting and assimilating fat, that is, in disease of the liver, as jaundice, and in certain cases of intestinal indigestion.

The presence of bacteria in milk greatly influences its acceptability in cases of sickness. One difference between cow's milk and human milk is found in the number and character of the contained bacteria. The method pursued in handling milk from the time it leaves the cow, if not before that time, will determine the number and character of the bacteria present. There is hardly any doubt that the objections to milk are chiefly due to the presence of bacteria and their products. When we remember that the number of bacteria in a given milk is proportionate to the skill and care with which it is handled, it is at once manifest that we are justified in demanding that the milk supplied should conform to certain reasonable tests, such as are exacted by various pediatric societies which certify the milk produced under conditions meeting their requirements. The tests are the result of much study on the part of the societies' committees and while they fix a high standard, it has proved to be a working standard, and one that can be obtained only by the most painstaking care with every detail of the processes of feeding, milking, and bottling. Milk secured under these conditions will keep for a longer period than that collected in the usual way.

It is interesting to note that fermentation changes in milk proceed from the surface toward the bottom of the container. So markedly is this the case that it is frequently possible to pass a tube through an upper layer of thick, sour milk and draw off sweet milk until only the layer of thick milk remains. This condition implies that the milk was practically sterile when bottled, and that the souring has been due to a later entrance of bacteria.

Pasteurization of milk is accomplished by subjecting it, by means of a water bath, to a temperature of 167° F. for a period of thirty minutes.

Sterilization of milk is accomplished by the same method followed in pasteurizing, except that the temperature to which the milk is subjected is 212° F.

Both methods have for their object the destruction of harmful bacteria. The consensus of opinion would seem to justify the statement that pasteurization will accomplish all that we ordinarily desire to attain by sterilization, and that it has the advantage of impairing the digestibility and the nutritive worth of the milk less than does the higher temperature. Infants fed upon sterilized milk are more likely to develop rickets and scorbutus than are those raised upon pasteurized milk.

There are numerous outfits in the market for the sterilization and pasteurization of milk, and with each of them will be found directions for use. If the patient is unable to procure one of the more pretentious devices for this purpose, he can accomplish the object by placing the milk in bottles of suitable size, plugging

them loosely with sterile cotton, standing the bottles in a kettle on a plate, piece of thin wood, or folded paper, and filling the kettle with cold water to a point on a level with the milk in the bottles. The water is then heated until it reaches the boiling point, and if the kettle is then removed to the back part of the stove, or the gas flame is lowered so that a temperature slightly below the boiling point is maintained, the milk will be pasteurized in thirty minutes. If it is desired to sterilize the milk, the water should be kept at the boiling point for the time specified. The milk should be cooled rapidly and kept in a cool place. The keeping quality of the milk will be proportionate to the number and character of the contained bacteria.

Pasteurized and sterilized milk, unless properly iced, will show a more rapid increase in the bacterial content than raw milk. Certain spores persist after ordinary pasteurization and sterilization. Complete sterility can be obtained only by fractional sterilization, a process almost never required.

Foreign Bodies in Milk.—An interesting object lesson in the *origin of the "cow odor" of milk* can be obtained by a visit to a creamery where milk, gathered indiscriminately from farms, is centrifuged. Here there can be seen thrown out from the milk a layer of excrementitious material that has gained entrance into the milk from the soiled teats of the cow, the dirty hands of the operator and the dust of the shed or pasture. Milk that has been properly handled should have no odor.

The question of administering whole milk may present one of two problems: First, how to change the taste in order to make it acceptable to the patient; second, how to modify the curd so that the enfeebled digestive power may not be overtaxed by the size of the curd formed.

To change the taste it may be administered cold, hot, sterilized, boiled, or skimmed, or with the addition of coffee, tea, chocolate, malt, liquor, or a spiced water, the latter to be prepared by adding boiling water to cloves, ginger, nutmeg, allspice, cinnamon, or a few bay leaves and allowing it to cool, then adding sufficient of this to the milk to change in a slight degree the flavor. These flavors can be changed at each feeding, or combinations of them may be used.

A satisfactory way to overcome the dislike of the taste of milk is to have it taken through a tube or a straw.

To modify the curd, have the patient *eat* the milk, that is, sip it slowly. If it is gulped down the curd formed will be large, especially if there is excessive acidity of the stomach contents. For this reason the use of a straw in taking milk is of advantage. The addition of an alkali to neutralize the excessive gastric acidity will lessen the size of the curd. For this purpose one may also use lime water or bicarbonate of soda. Simple dilution of the milk will make the curd smaller, and this may be accomplished by the addition of barley, rice, oatmeal, egg or carbonated water.

When there is a deficiency of acid secretion, it will be of advantage to add dilute hydrochloric acid drop by drop to the milk and give it with the flocculent curd suspended.

With adults, just as with infants, it is the casein of the milk which most frequently taxes digestion. If we are unable to secure the retention of the milk by any of the methods considered, it will be in order to change the casein into a more digestible compound by peptonizing it to a point where its further digestion can be accomplished by the enfeebled gastric secretion.

Buttermilk is deserving of more extended employment than is usual. It is digested with greater facility than sweet milk, has diuretic action and is often acceptable because of the taste or the ease with which it is digested, when sweet milk is not well received. The buttermilk remaining after milk has been used for butter making is almost devoid of fat, contains lactic acid bacilli of local origin, and is often objectionable because of the clumps of butter still present in it and the low grade of milk used in its preparation. Milk that would not meet the ordinary municipal requirements, not to speak of those for certification, is often sent to the creameries. Buttermilk from this source has high food value because of the retention of all of the casein and sugar, but for the reasons advanced it is often unsuitable for dietetic purposes. On the other hand, buttermilk prepared by using Bulgarian lactic acid cultures has a decided merit in that the highest grade of milk may be used, and the fat content may be regulated by the removal of varying proportions of the cream or by dilution with water. The best strains of lactic acid bacilli are thus introduced into the intestinal tract and a more uniform ingestion of them is secured. The following formula will give a delicious, well-proved preparation:

Dilute milk one-fourth in winter and one-third in summer. To each quart of milk add fifteen grains of salt dissolved in water and one lactic bacillary tablet crushed. Cover with a cloth and let stand in a warm place (70° to 90°) until slight coagulation has occurred and a distinct line has formed between cream and coagulated portion. Now place on ice until thoroughly chilled, then shake until smooth. It will require from twenty-four to seventy-two hours, according to temperature, to produce the effect desired; at about body temperature (100°) the action is quicker, but whatever the temperature, it should be kept as uniform as possible. Always shake thoroughly before using.

Peptonizing Milk.—This is accomplished by mixing a powder composed of five grains of extract of pancreatin and fifteen grains of bicarbonate of soda, or the contents of a peptonizing tube, with two tablespoonfuls of cold water, and adding it to a pint of milk. The milk is then placed in a vessel containing water at a temperature of 115° F. (or so warm that the hand may be immersed in it without positive discomfort) for five, ten, or fifteen minutes, according to the degree of digestion desired. There is developed, in the course of the process, a bitter taste proportionate to the time the milk is subjected to the action of the ferment. After the milk has been peptonized to the desired degree, it should be placed upon ice or quickly brought to the boiling point to check further digestive action by the ferment. It will be found satisfactory, in many instances, to mix the milk and the contents of a peptonizing tube, and allow the peptonizing to occur in the stomach. For this purpose put two tablespoonfuls of cold water in a goblet or glass; dissolve in this the powder contained in one peptonizing tube, then add fresh cold milk to fill the glass; stir this mixture thoroughly and drink immediately, sipping slowly.* Warm milk may be used instead of cold if the physician so directs.

The Administration of Milk.—There is no more important direction to be given to a patient than that milk should be taken slowly. If it is eaten, and not gulped, it will certainly be digested with greater facility. In many cases of persistent vomiting, milk will be retained if it is fed by the teaspoonful at short intervals. If it is desired to nourish the patient on an exclusive milk diet, it is well gradually to lessen the variety and quantity of mixed food, and at the same time increase the quantity of milk. It might be a source of discouragement to the patient to announce the quantity of milk you desire to have him take to the exclusion of all other foods; therefore let the transition be gradual and make it a matter of pride with the individual to take the six or nine pints of milk that it is desired he should consume in twenty-four hours as his only form of nourishment.

As the condition changes and demands a less strict

* Acknowledgment is due to Fairchild Brothers & Foster for the formula.

milk diet, the transition to a mixed dietary should be gradual. There will be manifest likelihood of harm being done to the circulation in any sudden withdrawal of so much liquid from the food.

The Quantity of Milk Required.—An adult in bed with an acute illness, such as typhoid fever, usually takes about three pints in twenty-four hours. This has always seemed a disproportionately small allowance for the adult, when it is remembered that the healthy child of one year of age is given two and a half pints. Emphasis is given to this disparity when it is remembered that the nutritive needs are proportionate to the amount of fever present.

The frequency of administration will be determined by the condition of the patient. If eight ounces are given every three hours from 7 A.M. to 7 P.M., and twice during the night, he will receive three pints. If he is given six ounces every two hours, and is fed twice during the night, he will likewise receive three pints. It is good practice to have the milk intended for the patient kept separate from that for household use, so that it may serve as a control record of the quantity administered in the twenty-four hours.

Fortified milk is prepared by the additon of nutritive substances, such as egg albumin, either fresh or dried, or whipped cream.

Milk may be introduced into the dietary in innumerable forms, and with little change in its character. Served under another name, and slightly different in taste, it is readily accepted by those who decline plain milk. One of the nicest preparations of this class is *plum porridge*, made as follows:

Raisins, minced, twelve; starch (potato or corn), one teaspoonful; milk, one pint. Heat the raisins and milk in a double boiler to the boiling point. Mix the starch with cold water and form a smooth paste; add it to the milk, keep it at the boiling point for five minutes, strain and serve. This preparation has a fruity taste, and is often accepted by an irritable stomach. It is of service in diarrhea.

Milk may also be administered in the form of pap, junket, whey, koumys, zoolak, matzoon, bonny-clabber, curds and whey, cottage cheese, custards, and a great variety of prepared dishes which have milk as their chief constituent.

Koumys is prepared by taking one quart of milk, heated to about 100° F., a tablespoonful of sugar dissolved in a cup of hot water, and a fifth of a yeast cake dissolved in a tablespoonful of cold water. Mix and put in strong bottles—beer or citrate of magnesia bottles are sufficiently strong. Let the bottles stand in a warm place, above the range, for twenty-four hours; then place on their sides in a cool place, *e.g.* the cellar in summer, or some place where the temperature will be about 60°, for six days. It will require less time, if it is kept in a warmer place. The koumys is then ready for use, and should be drawn off with a champagne tap, because of the likelihood of losing a large portion of it if the cork is removed. The acidity and taste of the preparation will be influenced by the length of time fermentation has continued, and the temperature at which it has occurred. A koumys having a flavor and digestibility suited to the patient may usually be secured by attention to these details.

Milk Jelly.—Heat one quart of milk; then add and stir until dissolved one pound of granulated sugar; allow to boil for ten minutes; then let cool, and when cold add, with constant stirring, one ounce of gelatin dissolved in four ounces of water; when well mixed add the juice of three lemons mixed with a half cupful of sherry wine or good whiskey. Pour into cups, and keep in a cool place. Serve warm or cold.

Junket.—Milk, half a pint; warm to blood heat. Sweeten and flavor to taste. Add the half of a rennet tablet, dissolved in a dessertspoonful of water or a teaspoonful of essence of pepsin. Stir. Do not place upon ice until it has thickened.

Bonnyclabber.—Skimmed milk, preferably in a glass dish, is allowed to thicken spontaneously. This may be fortified by the addition of whipped cream and egg albumin.

Pap.—Flour, one tablespoonful; milk, one pint. Cook ten minutes. The white of an egg may be added.

MEAT. The use of meat in the dietetic treatment of acute disease is generally confined to the administration of beef, mutton, or chicken, in the form of a fluid representing the soluble constituents of the meat albumin, extractives, salts, etc.

Raw meat is easily digested and when scraped is serviceable in certain intestinal diseases. There is, however, some risk of tape worm associated with its use.

The cooking of meat is resorted to for the flavors it develops and for the purpose of making the connective-tissue fibers more tender.

The method pursued in the preparation of these foods will determine their nutritive worth. Thus, beef tea will be a stimulant if the protein of the preparation is strained from it after it has been coagulated by the application of heat. Beef tea, subjected to a temperature of 212° F., retains in solution only the salts and extractives of the meat, and to these constituents it owes its stimulating property. On the other hand, beef tea is a food if it is prepared in a way to secure the retention of the protein in the finished product.

In selecting the form of beef for a patient, we must be influenced by his digestive capacity. Thus we may give a dilute extract of beef having mildly stimulating properties, or we may select preparations having progressively increasing proportions of nutritive worth, even ordering the entire beef, in which case we should have to consider only the method of cooking it.

The digestibility of the various meats is determined by so many modifying influences, such as the age and condition of the animal supplying the meat, the time that has elapsed since it was killed, the method of preparation, and the digestive power of the individual, that it is not possible to do more than to state approximately the relative digestibility of the various forms of meat.

The order of facility of digestion, other things being equal, is as follows: Oysters, eggs, sweetbread, tripe, calves' brains, white fish, white meat of chicken, beef, mutton, squab, fish, dark meat, game, veal, pork.

The color of meat is influenced by the distribution of the contained fat. The marbling of red meat is due to the fat. The white meat of fowls is very deficient in fat; in this case it is collected in layers and distributed about the white meat. The dark meat is richer in fat, and requires greater digestive power. This fact will influence the selection of fish, fowls, and beef. The fat of mutton has a higher melting point than that of beef and fowls, and for this reason it sometimes occasions indigestion. Cold mutton, in which the fat can be readily separated, will frequently be found acceptable when the recently cooked mutton cannot be digested.

Taking up first the mildest preparation of beef which we are able to offer the patient, we may consider:

Stimulating Beef Tea.—The choice of the cut of beef in making various foods for the patient is of little importance, aside from the question of cost. The meat from the neck will give a preparation quite as nutritious as that made from meat taken from the round steak. Take one pound of beef from the neck, put it twice through the chopper, and place it in a porcelain-lined kettle; add one pint of cold water. Allow it to macerate in a cool place for three hours, occasionally stirring with a wooden spoon. Heat the preparation to the boiling point, and allow it to simmer for one hour. Season it to taste. Strain through a double layer of cheese-cloth, cool rapidly, remove the

fat, keep securely covered. If it is desired to have a preparation that is perfectly clear, the well-beaten white of an egg may be added, and the tea heated to the boiling point and then strained. This preparation is mildly stimulating and may induce wakefulness in those cases in which a stimulant would produce such an effect, and it is not to be relied upon as a food. All of the beef tea made from the solid extracts of beef furnishes a product of no nutritive worth.

Beef Extract by the Cold Process.—Minced beef, five ounces; cold water, a pint; hydrochloric acid, five drops; common salt about twenty grains. Macerate in a cool place for three hours, strain through a sieve, and wash the residue with sufficient water to make the finished product measure a pint. Remove the fat, and serve warm or cold.

Nutritive Beef Tea.—Take one pound of beef from the neck, remove the excess of fat, and put it twice through the chopper. Add one pint of cold water, and place in a quart jar. Macerate in a cool place for three hours, with occasional stirring. Make a water-bath, and have the water of the bath extend to the level of the beef and water in the jar. Stand the jar in the water-bath, and heat slowly until the water in the water-bath reaches the boiling point. Lessen the heat and continue its application, not allowing it to reach the boiling point, for a period of three hours. Strain through a sieve, and wash the residue with enough water to make the finished product measure a pint. Season to taste, cool rapidly, and remove the fat. Keep the tea as nearly sterile as possible. Should the patient tire of the flavor of this preparation the taste may be modified by the addition of various aromatics, such as bay leaves, mace, cloves, some minced celery, or aromatic herbs. This preparation if not subjected to too much heat should have a reddish-gray color, and possess nutritive worth. If the whites of several eggs are added to the nutritive beef tea, a more meritorious food will be provided.

Bouillon is a dilute form of stimulating beef tea. A shin bone is usually used in its preparation.

Consommé is bouillon flavored with herbs and colored with caramel. The advantages of these two last-named preparations are that we are able to secure them from the hotels and restaurants, and in ordering them for a patient we apparently make a concession to the taste of the individual.

If a stronger beef preparation is desired, we may give beef juice made by taking meat from the neck, cutting it in slices about an inch thick, broiling it slightly in order to start the juices, then cutting the meat into cubes and subjecting it to pressure in a meat press designed for the purpose. The press should be heated before use by pouring boiling water over it, so as not to chill the meat; a warm cup should receive the meat juice, and the meat should be fed into the press in small quantities. In giving the preparation to diphtheria cases salt should not be added, unless it is found necessary to do so, because that contained in the beef is quite sufficient, and any addition of salt would cause smarting of the inflamed mucous membrane. The neck or tender side of the round steak will yield about six ounces of juice to the pound of steak. If beef juice is to be prepared for any length of time, it is more economical to buy a meat press rather than yield to the temptation to temporize with a potato-masher. This is a concentrated form of nourishment, and one well adapted for administration to typhoid-fever patients with perforation or hemorrhage. The residue leaves little to irritate the ulcerated area.

Scraped beef cakes constitute a more concentrated as well as a more digestible form of nourishment than whole beef. They are prepared by taking a steak from the tender side of the round, and, with a knife that is not too sharp, scraping it in the direction of the fiber until the pulp of the meat is removed, leaving the connective tissue. The pulp is then gently pressed into a cake of uniform thickness and is broiled over the coals or in a dry pan. Seasoning and butter should then be added, and the cake put into the oven so that the seasoning may become uniformly blended with the meat pulp. The flavor of this preparation may be changed by adding minced celery, almonds, or pine nuts, and its nutritive worth may be increased by the addition of various nuts, butter, or egg albumin.

Raw beef soup may be made by taking the pulp of beef, prepared as above stated, and mixing it with water sufficient to give it the consistence of a cream soup. Salt, pepper, or celery salt may be added, and the preparation may be slightly warmed, if more acceptable to the patient in that condition. This preparation has a field of usefulness in dysentery and certain forms of summer complaint.

Minced meat cakes may be prepared by putting a choice cut of beef twice through the chopper and making it into cakes as was directed in the preparation of scraped beef cakes.

If we would give beef in its entirety, it would be best to select the tender side of a sirloin, which will be more tender than any other part, even if it is less juicy. The convalescent is disinclined to make much effort in masticating food, and this necessitates the selection of tender meats, or the preparation of them in a way that will require a minimum amount of effort.

Mutton broth is prepared by the same method, and the meat is used in the same proportion as directed in the preparation of beef tea. The fat of mutton is less digestible than that of the beef, and care must be exercised to remove every particle of it. An additional reason for getting rid of the small globules of fat is found in the tendency of these particles to float on the surface of the tea and attach themselves to the lips of the patient, leaving a disagreeable aftertaste.

Chicken Jelly.—In making chicken broth it is best to select an old fowl. Crack the bones, cover the meat with water, and heat to the boiling point, and continue the application of heat a little below the boiling point for three hours, adding water from time to time to replace that lost by evaporation. Strain through a colander, wash the residue with hot water sufficient to make a pint of fluid for each pound of chicken used, season to the taste, and pour into suitable small moulds. When cool remove the fat with a spoon and damp cloth. Serve cold in the form of cubes, or allow it to retain the shape of the moulds; or it may be warmed and administered as a broth.

Chicken Panada.—Chicken (white meat, raw), one-fourth pound—chop and rub fine; fresh bread crumbs, four ounces; milk, four ounces; whites of two eggs, well beaten. Season and poach in small cups.

Veal Broth.—Veal, chopped fine, one-half pound; cold water, one pint. Macerate for three hours. Water-bath for three hours. Strain, season, cool, and remove fat.

Eggs.—Eggs are rendered unfit for food purposes by decomposition induced by bacteria which penetrate the shells. The freshness of an egg can be estimated by the jelly-like condition of the white and its freedom from a watery portion. Staleness is indicated by a loss of weight, due to evaporation of the water. A stale egg will also give a splashing sound when shaken. Testing by specific gravity and candleing will determine the freshness of eggs, but is hardly to be regarded as applicable to household adoption.

Unbeaten raw eggs will be accepted by a patient in larger numbers and over a longer period than when shaken up with milk or cooked. They may be taken in remarkably large numbers, as many as fifty a day.

Some patients experience difficulty in digesting the yolks of eggs, especially if they are not strictly fresh. In these cases we may give the raw whites of a

number of eggs, cut into small masses with scissors, with sherry, milk, or orange juice for flavor, if the patient has tired of the whites alone. After a time the yolk of one egg may be added to the whites and it will be readily accepted. The flavor and odor of eggs and the color of the yolk are greatly influenced by the food upon which the fowl has fed.

The chemical composition of eggs is as follows:

	White.	Yolk.
Water	86.2	49.5
Protein	12.3	15.7
Fats	0.2	33.3
Mineral matter	0.6	1.1
Calories per pound	250	1,705

The white is very easily digested if given raw or very slightly cooked. If well beaten or but slightly cooked, or if it is added to water, it will be found more digestible in some instances than milk.

The large percentage of oil contained in the yolk would indicate its value in those patients who need oil and are able to digest it. It should be slightly cooked. If it is to be given hard boiled, it should be heated until it is mealy and then grated or passed through a sieve.

Eggs may be prepared in many ways. If fresh they are easily digested, and furnish a concentrated form of nourishment.

Eggs should not be subjected to a high temperature in their preparation. A satisfactory method for preparing a soft-boiled egg is to place one egg in a cup containing one-half pint of water heated to the boiling point and allowing it to remain for ten minutes. The cup should not stand on marble or metal, since the cooling of the water would be too rapid for the purpose in view.

A poached egg should be prepared by dropping an egg into water near the boiling point to fix the albumin. It should then be basted with water of a lower temperature, about 170°, until there is a veil over the yolk, and the white of the egg is jellified. An egg prepared in this manner may be given when one poached in the usual way would not be tolerated.

Albumin Water.—The white of one egg well beaten; water, one half-pint. Mix and strain. It may be flavored with sherry or lemon or orange juice.

Egg Custard.—One egg, beaten; milk, four ounces; sugar, one tablespoonful. Mix and put in cups and bake.

Chocolate Custard is made by adding sufficient chocolate to flavor and color the egg custard.

Caramel Custard is made by adding sufficient browned sugar to impart a caramel flavor to the egg custard.

Brandy-and-egg Mixture.—Yolks of two eggs; sugar, one heaping tablespoonful; brandy, two ounces; cinnamon water, four ounces. Mix. Administer in tablespoonful doses.

Egg Lemonade.—White of one egg, well beaten; juice of one lemon; sugar sufficient; water, one-half pint. Shake thoroughly. Strain.

Egg Flip.—Milk, hot, one-half pint; yolk of one egg, well beaten; whiskey one ounce. Mix.

Egg Nog.—Put the yolk of one egg with a tablespoonful of whiskey or brandy, a tablespoonful of Jamaica rum, and a tablespoonful of granulated sugar, with a half pint of whole milk into a pint jar, and shake thoroughly until the sugar is dissolved. Beat the white and add most of it to the mixture, and shake again. Put the remainder of the beaten white on the top of the drink, and have the patient take it through a tube or straw.

Bartholow's Food.—Sago, one ounce; milk, one-half pint. Soak for ten minutes, then place in water-bath until clear. To this add: Stimulating beef-tea, one-half pint; yolk of one egg, beaten; celery salt, sufficient. Mix. This is a complete food.

Fish.—The digestibility of fish is influenced by the kind, quantity, and distribution of the oil contained in the meat; and by the season, the freshness, and the method of preparation of the fish.

The blue, dark, and red meats of fishes are due to the presence of oil or fat. In white fish the fat is collected in local parts, and, for this reason, white fish may be given to those who cannot digest the oil contained in the dark meat.

For the sick, fish should be broiled, and the amount of fat desired should be supplied in the form of melted butter used as a dressing.

If the fish is prepared by being plunged into boiling salted water, and the process of cooking is continued with the water at a slightly lower temperature, it will retain almost all of its nutritive worth.

Oysters.—Oysters contain a small proportion of nourishment, and are easily digested if the "eye" is rejected. The juice, prepared by mincing a dozen fat oysters with a silver knife and putting them into a fruit jar and standing the jar in hot water for a half-hour, is often accepted by an irritable stomach that refuses almost all other forms of nourishment.

Oyster Soup should be prepared by taking some flour and butter and mixing them, with the cold milk, gradually added, and then adding the liquor drained from the oysters. This mixture should be boiled for five minutes, and the oysters and seasoning then added; the soup should be served at once. Prepared in this manner the oysters should be plump rather than shrivelled, and the soft parts may be eaten by the patient who is able to digest solid food.

Oyster Broth.—Oysters, twelve; water, two ounces. Mince the oysters. Place over water-bath for a half-hour. Season. Strain.

Clams.—Clams have a place in the dietary of the sick chiefly for the juice, which is very acceptable in a great variety of cases.

To prepare clam juice take six large clams in the shell, scrub the shells, put them into a kettle, add a cup of water, heat until the shells open, pick out the shells and clams with a fork, strain the liquor through a double layer of cheese-cloth, cool rapidly, keep well corked and cool, and dilute with hot or cold water to suit the taste of the patient. Some persons will accept the juice if it is diluted until it has only a suggestion of the clam flavor, who would be unable to take it if it were stronger.

A cream of clams may be made by adding milk and enough flour to give the density desired.

Vegetables.—*Classification.*—Cereals, legumes, roots and tubers, green vegetables, fruits, nuts, fungi, lichens. *The green vegetables* possess low nutritive worth. They are difficult to digest because of the large percentage of contained woody fiber, and many are not available for food purposes until they have been cooked. They are valuable for the volatile oils, mineral matter, organic acids, and the large proportion of water they contain.

The cereals approach in character a complete food by reason of the contained gluten, starch, and fat. The proportion of nitrogen is not sufficient, however, for bodily needs without a supplemental supply in other forms of food. The distinguishing advantage possessed by them is that certain of them can be made into bread. Much of the nitrogenous worth of the bread prepared from wheat is sacrificed to the desire for whiteness. The gluten layer of the wheat grain is located directly under the outer bran coat of the grain, and if this were allowed to remain it would give a darker color to the flour and the bread prepared from it. *Whole-wheat bread* contains the gluten and the phosphates of the grain, and for this reason is

darker and more nutritious, and because of a small proportion of bran associated with the flour is helpful in overcoming constipation.

Legumes contain nitrogen in the form of protein, in addition to starch and fat, and are represented by peas, beans, lentils, and peanuts. They may be termed vegetable meat because of their large percentage of nitrogen, and are more valuable as foods because of the iron and sulphur entering into their composition. It is very difficult to secure all of the nutriment contained in them because of the intimate association of the protein and starch with the cellulose and the dense capsule substance surrounding them. For those having feeble digestion they should be thoroughly cooked and passed through a colander to get rid of a large proportion of the associated woody fiber.

Roots, tubers, etc., depend upon the contained starch, sugar, salts, and acids for their nutritive worth. Here the food value is lower and less concentrated than in the case of cereals and legumes, and they are poorer in nitrogen. The digestibility will vary according to the age and to the proportion of water lost by evaporation. The starch derived from corn and potatoes, arrowroot and rice, will tax the digestion least. Starches having a cell wall are available as foods only after they have been cooked sufficiently to cause the rupture of the retaining membrane so as to liberate the starch.

Fruits.—Fruits are valued for their antiscorbutic properties, due to the salts, acids, alkalies, volatile oils, ethers, and the large percentage of water which they contain. They do not possess high nutritive worth.

Nuts are rich in fats and possess high calorie value. Most of them are rich in proteins and are relatively poor in carbohydrate. Because of the high fat and low carbohydrate content (with the exception of chestnuts) they are very serviceable in diabetes. They are all difficult of digestion because of the large amount of cellulose. They should be thoroughly masticated or ground into a paste.

Roasted almonds and *pine nuts* add a pleasant flavor to meat cakes and are serviceable as relishes with the ordinary meal.

Fungi.—Mushrooms are not now regarded as possessing the high food value which was formerly attributed to them. As a seasoning they, as well as truffles, serve a useful purpose.

Bread.—Bread for the sick should be thoroughly baked in loaves small enough to insure the destruction of the yeast plant at all parts of the sponge. Freshly baked bread is unsuitable to patients needing dietetic directions. Rasped rolls and thoroughly baked rolls are better than bread cut from the loaf.

Toasted bread should be prepared from stale bread, slowly heated over the fire until it is cooked throughout its entire thickness, is crisp and has a golden color. The crust should be removed.

Pulled bread is prepared by taking a loaf of Vienna bread two days old, removing the crust, and separating the sponge of the bread with two forks, or the thumbs, in such a way that the bread is not crushed. Make into strips about four inches long and one inch thick. Place in a pan, the bottom and sides of which have been covered with paper, and bake in the oven until of a golden brown color and thoroughly crisp. It may be served with cream or whipped cream.

Dextrinized bread is prepared by heating a slice of stale bread in the oven until it is of a dark brown color.

Torrefied bread is prepared by subjecting bread to a greater heat for a long period than is used in preparing dextrinized bread.

Brown Flour Soup.—Heat flour in a pan until it has a walnut color. Add a little butter. Form a smooth paste by the addition of hot water, and continue the addition of hot water until sufficient has been added to make the consistence that of a cream soup. Cook for five minutes. Season to taste.

Drinks and Jellies.—There is a class of preparations possessing refrigerant, demulcent, diuretic, diaphoretic, and astringent properties. They have a wide range of usefulness, and the variety of them at our disposal enables us to cater to the taste of the patient.

Flaxseed Tea.—Flaxseed, one tablespoonful, to be washed with cold water; water, one pint. Boil thirty minutes; sweeten; flavor with lemon peel or juice; cool; strain.

Gum-arabic Water.—Gum arabic, one tablespoonful; sugar, one heaping tablespoonful; water, one pint. Dissolve by means of a water bath. Add lemon juice, one tablespoonful. Strain.

Irish-moss Tea.—Irish moss, one ounce, to be washed with cold water; water, two pints. Mix and allow to stand for fifteen minutes; heat to boiling point; add lemon juice, two ounces; sugar, two tablespoonfuls. Strain.

Irish-moss Jelly.—Irish moss, three ounces, to be washed with cold water; water, one pint. Allow to stand fifteen minutes; heat to boiling point and continue at that temperature for five minutes. Strain. Add sherry wine, two ounces; sugar, two tablespoonfuls. Put in moulds to solidify.

Imperial Drink.—Cream of tartar, one teaspoonful; boiling water, one pint; lemon peel and sugar, of each a sufficient quantity. Mix, cool, and strain.

Wine Whey.—Milk heated to boiling point, one-half pint; sherry wine, two ounces. Mix and strain.

Alum Whey.—Milk heated to the boiling point, one-half pint; powdered alum, one teaspoonful, dissolved in water. Mix and strain.

Lemon Whey.—Milk heated to the boiling point, one-half pint; lemon juice, two teaspoonfuls. Mix and strain.

Rice Water.—Rice, one tablespoonful, to be washed. Then add boiling water, one pint, and boil for half an hour. Add lemon peel sufficient; cool. Strain.

Toast Water.—Toast thoroughly a slice of bread. Pour over it six ounces of boiling water. Cover. Allow to stand in a warm place for fifteen minutes. Administer by the teaspoonful.

Corn Water—Brown a tablespoonful of corn meal in a pan; add six ounces of hot water: boil for five minutes. Strain.

Barley Water.—Pearl barley, two ounces, to be washed; water, four pints. Mix and boil to two pints. Flavor, sweeten, and strain.

Barley Water with Patent Barley.—Patent barley, two tablespoonfuls; cold water, two tablespoonfuls; salt, sufficient; sugar, one tablespoonful; boiling water, one pint. Mix and boil for five minutes.

Dietetics for Particular Diseases.—*Stomatitis.*—Hot water taken freely an hour before meals is of great service. If bicarbonate of soda is added to the water the effect will be better. A milk diet with pulled bread or dextrinized bread is best. White meat may be allowed in small amounts. Ice cream, iced fruit juices, junket ice cream, and albuminized beef tea may be given. Acids and fats are to be avoided, as are foods likely to undergo fermentation.

Tonsillitis and Pharyngitis.—There is usually associated with these diseases a mild febrile process, and the same diet is suitable to both conditions.

Diluent and demulcent drinks, such as rice water, barley water, or oatmeal water, are nutritive and serviceable. Irish-moss tea or jelly flaxseed tea, gum-arabic water are soothing, alum whey is astringent, and imperial drink is refrigerant.

The proper diet should be one containing a large quantity of water. Whole or skimmed milk, or milk with barley or rice water, is to form the chief article

of diet. Alum whey is of service because of its astringency, and because it enables us to vary the diet. Junket, milk jelly, water ice, and ice cream are allowable. Gruels and creams of various vegetables may be given. Animal broths should be omitted, except those prepared from oysters and clams. The subject will be fully considered in the section devoted to the Dietetics of Diphtheria.

Stenosis of the Esophagus or of the Cardiac End of the Stomach.—The character of the cause of the stenosis will influence the selection of the diet, as will likewise the degree of obstruction. Milk, plain and modified, is to be considered the standard diet. A complete food is to be constructed from milk, eggs, and cereal. We have an example of such in "Bartholow's food." Scraped beef and finely minced chicken can be combined with milk and, in case of deficient digestive power, these combinations may be peptonized. The semi-solid foods, such as wine jelly, calf's-foot jelly, gelatin preparations, bromangelon, junket, and ice cream are easily swallowed.

Acute Gastritis.—The temporary avoidance of food administered by the mouth is frequently the prime indication. If the strength of the patient is exhausted, it may be necessary to resort to rectal alimentation. Cracked ice may exert a quieting influence upon the gastric irritability. Hot water is of the greatest service even when it is not retained. More acceptable and likely not only to be retained but also to allay vomiting, is clam juice. For the earlier stages there is nothing better than this preparation. The method of administering it and all nourishment in this condition is quite as important as the selection of the particular kind of food. A teaspoonful of liquid food given every five or ten minutes, or every minute, until four or eight have been given, is much more likely to be retained than are larger quantities. After the irritability of the stomach has once been allayed and digestion begins to be performed, the interval between feedings and the quantity and variety of food may be increased. Milk with carbonated water, whey, junket that has been passed through a colander or sieve, albumin water, koumys, or zoolak may be given. Toast water or corn water and dry toast will often allay vomiting. Oyster juice fed very slowly is serviceable in these cases; later, scraped beef and chicken panada, or the white of a poached egg with pulled bread, will be acceptable.

Chronic Gastritis.—The condition with which the gastritis is associated will influence the choice of diet. The liberal use of hot water, or hot water with bicarbonate of soda and essence of peppermint, will facilitate the removal of the tenacious mucus so constantly present in these cases, and give a better opportunity for the gastric secretion to act.

The condition is so constantly associated with obstruction of the portal circulation that no food must be given that would tax the hepatic function. For this reason buttermilk, which represents sweet milk with practically all of the fat removed, is regarded by many as the ideal diet for these cases. Skimmed milk is serviceable for the same reason. Milk, diluted with hot water, with carbonated water, or with a water prepared from one of the cereals, to render the curd smaller, is to be regarded as especially indicated.

It is a safe general rule in dietetics to give that food which will tax the affected organ least—in other words, to rest the disabled viscus. This rule would indicate the use of fats and starches in gastritis. Fats are contraindicated, however, for the reason given. Starches are of service in many of these cases, but their use must be watched because of the liability to occasion the development of water brash, or heartburn, due to lactic or butyric acid fermentation. Corn-starch, arrowroot, and white potatoes should furnish a starch most easily digested. It need hardly be added that care and skill in the cooking of these cereals will greatly influence their digestibility.

The stimulating beef tea in the earlier stage, and the nutritive beef tea when the condition improves, will be found serviceable. Scraped beef, or beef reduced to a pulp by means of a mortar, and the fibers drained from it, will be easily digested. The judicious use of condiments in these cases will be of service in stimulating the gastric secretions.

One thought is to be kept constantly in mind in the treatment of these cases—that is, that no food shall be given that is liable speedily to undergo fermentative changes, or to remain long in the stomach. For this reason, spare, cold boiled ham, and other smoked meats are often more acceptable than other forms of nourishment.

In those cases in which the disease is associated with deficient motor power, the interval between feedings should be lengthened, and an effort made to cleanse the stomach of the remnant of the previous meal before more food is introduced.

Eggs are more available if the whites only are used. They should be poached at a low temperature, or well beaten, and should be combined with other forms of nourishment. Oven-baked toast, or pulled bread, will be the form of bread least likely to induce flatulency.

Dyspepsia.—The term is applied to a group of symptoms including those previously considered under acute and chronic gastritis. In addition to these two classes of gastric diseases, there are cases with symptoms so pronounced as to enable them to be considered under the following heads: Atonic dyspepsia; nervous dyspepsia, including gastralgia; intestinal dyspepsia.

Atonic Dyspepsia.—Hot water should be given immediately upon rising to cleanse the stomach of accumulated mucus, and a glassful of cold water before meals for its tonic effect. See to it that there are teeth to perform the work of preparing the food for digestion. It is more promising to treat certain dyspeptics by ordering teeth than by the employment of countless drugs and diets. When the teeth are unsuited to grind and cut the food, it must be artificially done or the diet will have to be confined to the foods requiring no mastication. The condition of the teeth and gums, as possible sources of infection, is to be given careful consideration. Each meal should consist of one or two articles of diet. Beef combined with rice will give a complete food because there is sufficient fat inseparably associated with the beef to yield as much of this food element as is likely to be digested with facility.

Fruits are of service in this case, especially if taken before the meal. Those containing a minimum of acid, such as oranges and grapes, if taken before breakfast will frequently stimulate digestion. Certain cases will be met with in which the fruits are better borne if taken at the close of the meal. This is particularly true of the more acid fruits, such as strawberries.

For breakfast, a broiled chop, the white of a poached egg, a cereal, if thoroughly insalivated and if not too much sugar is used, combined with toasted or wholewheat bread, or shredded wheat, would make a suitable meal. Cambric tea is to be preferred to tea or coffee. For dinner, a cup of hot stimulating beef tea, consommé, or bouillon will stimulate digestion. This may be followed by a meat cake, prepared by passing beef twice through the chopper or by scraping it. A mealy baked potato is allowable, and this may be made more digestible by having the potato removed from the skin after baking, incorporating with it butter and seasoning and, in certain instances, the white of an egg, replacing the mass in the potato case and heating so that the seasoning may be thoroughly blended and the starch granules separated. Steamed rice, macaroni, vermicelli, or any of the Italian pastes may be given, and when combined with grated Parmesan or American cheese will constitute a complete food. If the diet is confined to one or two

articles of food we are able readily to determine the influence of the food elements administered upon the course of the disease. This point is not sufficiently appreciated, and its neglect often results in failure in the dietetic treatment of disease. When there is hyperacidity, scraped beef as an exclusive diet will often give the best results. In those cases in which there is a hyperacidity the starches, if thoroughly insalivated, are apt to be more easily digested.

Water with the meals is of advantage because of its solvent effect and its mechanical aid in separating the particles of food and thus facilitating the action of the gastric juice upon the aliment. Constipation is a less prominent symptom when sufficient water is taken. Too much water, on the other hand, may retard digestion by excessively diluting the digestive ferments. Rest after meals promotes digestion; sleep retards it.

Nervous Dyspepsia.—In these cases the disease manifests itself by symptoms referable to the nervous system and associated with these there are variable appetite, clean tongue, and a pain in the region of the stomach, which latter is often relieved by taking food. The element of pain may be so pronounced as to justify considering the case one of gastralgia. According to the degree of severity of the symptoms will be the necessity for a rigid dietetic regimen. Rest before and after food is most helpful. The meals should be taken under a cheerful environment. Anything tending to depress, irritate, or call attention to the patient's invalidism is to be avoided. An exclusive milk diet may be necessary. Later, fruits, eggs slightly cooked, bacon crisp and dry, with dextrinized bread, should compose the breakfast. Coffee is to be avoided, and tea also, unless it be weak and freshly brewed, and taken several hours after the meal.

Ulcer of the Stomach.—The inability to determine how long the condition has existed makes useless any effort to regulate the diet to suit any particular week of the disease. The occurrence of hemorrhage is a definite landmark of the course of the lesion.

As soon as the disease is recognized the patient should be put to bed.

When hemorrhage has occurred, all food by the mouth should be withheld and rectal feeding substituted for several days, a week or until all signs of hemorrhage have disappeared. The objection to rectal feeding in peptic ulcer is the absence in the stomach of food necessary to neutralize the gastric juice which is called forth by the stimulation excited by the rectal alimentation. It may be better to withhold all forms of nourishment or to administer milk by the mouth. Later, white of egg, cream, and gelatin may be given. The patient should be confined to bed for several weeks.

Olive oil given before meals, has been recommended with a view of combating the tendency to hyperchlorhydria and pyloric spasm.

Lenhartz advocates a suitable dietary in all stages of the disease capable of combating the debility, anemia, and the administration of protein to lessen the hyperacidity and nourish the patient. An ice-bag is applied locally, bismuth is given internally and ice-cold milk and eggs are administered, even when hemorrhage is present.

The rule to spare the affected part applies with special force to this condition. The ulcerated gastric mucous membrane must not be irritated by coarse food, excessive food, or a free flow of gastric juice, because the likelihood of hemorrhage is increased by coarse particles of food, and by distention of the stomach by food or gas. Carbonated water is not to be used in diluting the milk that is so large a part of the diet, unless the mixture is allowed to stand until effervescence has entirely ceased. Milk, prepared in this way, will form a flocculent curd. Rice or albumin water will be serviceable as an addition to the milk. Curds and whey, if passed through a sieve, may be used.

As convalescence becomes established, the patient may have cream soups of the various vegetables, always observing the precaution that they be strained through the colander or sieve. Meat soup, free from fat, scraped meat cakes, or minced white meat of chicken, creamed sweetbreads, and strained gruels, or combinations of these food elements, may be employed in these cases.

The dietetic treatment of a case of gastric ulcer should extend over a period of from four to six months.

Intestinal Dyspepsia.—Most conducive to relief from digestive disturbances is a regard for the rules that may be applied to all dietetic efforts. These comprise a favorable environment, careful mouth toilet, correct temperature of the food, fixed hours of feeding and a suitable interval between meals, slow eating, thorough insalivation and a period of rest before and after meals. It is not difficult to appreciate that the most probable exciting cause of this condition is to be found in the excessive use of improperly cooked starches. Potatoes, yielding themselves to many improper methods of cooking, are doubtless potent factors in the production of intestinal dyspepsia. Here the starch is made difficult of digestion by reason of the frying to which it is often subjected, and the fat used in the process has been heated to a point where its chemical composition is changed, when it becomes unsuited for food purposes, as is starch which has been cooked in it.

The breads usually found on the table are frequently of such composition or in such a condition as to make them a tax upon digestion. Among the poorer classes the meal is often largely made up of bread and a liberal allowance of tea and sugar. There is another class of food stuffs that have contributed largely to the causation of this disease, the cereals; the coarse oat-meals that have been cooked for as brief a period as a half-hour are better adapted for bill-posters' buckets than for human stomachs. The treatment of the condition after the elimination of the exciting cause resolves itself into the administration of the foods that are digested chiefly in the stomach. Hot water, skimmed milk, milk in all possible combinations, and milk with the curd made small, will be found serviceable in all of these cases.

Clear soup made from meat, and scraped or chopped meat cakes with dextrinized bread, will stand for the diet best adapted to these cases. These articles of diet are quite sufficient for a considerable period of time if prepared in the various combinations to which they lend themselves. Later, slightly cooked egg albumin may be added to the diet, and as the condition improves, sweetbreads, calves' brains, squabs, chicken, bacon, and game. The starchy foods are to be added gradually and the effect watched. Macaroni, vermicelli, and noodles, steamed rice and corn starch, and, later, a baked potato may be added to the diet.

Tea and coffee, as they are usually prepared and used, are objectionable in all forms of dyspepsia. Coffee if diluted with hot milk is less likely to tax the digestion than is tea. The question of stimulants and wine is a less pressing one here than abroad. For the debilitated or aged, champagne, or brandy diluted with carbonated water, when taken during the meal, will frequently prove of the greatest service.

Cancer of the Stomach.—If the lesion is situated at the cardiac orifice and is sufficient to prevent the ready entrance of food into the stomach, it will become necessary to use the stomach tube in feeding the patient. If the pyloric orifice is the seat of disease, the likelihood of gastric dilatation and its attendant catarrh is proportionate to the degree of stenosis. The food in either instance should be either liquid or semi-solid. Milk combined with eggs, beef, or one of the starchy vegetables will offer a sufficient range of nourishment. The white of egg may be given with

milk or broth. The yolk can be administered with less objection in these cases, especially it it is associated with pancreatin and soda.

Scraped beef, beef peptonoids, and strained gruels are to be given.

An early, careful employment of rectal feeding will prove a valuable supplemental source of nourishment. Later, it will likely be the only means of sustaining the patient.

Pyloric Obstruction and Dilatation of the Stomach.—The diet suitable for chronic gastric catarrh and cancer of the stomach, with certain slight modifications, will be found adapted to these conditions.

Constipation.—One of the most important directions that can be given a patient with this troublesome complaint is that a hard-and-fast rule be observed in the matter of having a fixed hour each day, at which an effort to have a bowel movement will be made. A glass or two of hot water, sipped at intervals during the progress of the toilet, and, if necessary, the same quantity of water taken before retiring, will greatly favor a daily evacuation of the bowels.

The condition is constantly associated with a deficiency of the liquid element in the intestinal contents. Either there is a deficiency of water ingested, or that taken is lost by excessive perspiration, and the fecal matter in this way becomes inspissated and constipation results.

Fruits, either raw or cooked, and dried fruits according to the digestive power of the individual, are of the greatest service in overcoming constipation. They act more by virtue of the acids and the water contained in them than by their bulk and mechanical irritation of the intestinal tract.

Most of the dried fruits are more easily digested if cooked. *Prunes* should be deprived of the skin, and thorough mastication of the fruits having much woody fiber should be insisted upon.

Vegetables, especially the green vegetables, *e.g.* spinach, lettuce, peas, beans, celery, and others, by reason of the water and acids they contain and the residue they leave, contribute to overcome constipation.

When it is remembered that approximately more than three-fourths of most vegetables are composed of water, it will be more readily appreciated how these foods exert an apparent effect by liquefying the intestinal contents.

When the constipated habit of the meat-fed dog is contrasted with the semi-solid character of the evacuation of the herbivorous animals we have an important dietetic suggestion.

Cereals are helpful in the treatment of these cases, if they are prepared in such a way as to leave the bran layer of the grain in the meal.

In this way we secure, by bulk and mechanical irritation, a stimulus to peristalsis. Bran bread, ginger bread, graham bread, brown bread, the various cereals comprising the breakfast foods on the market, and the gluten, ginger, and smaller biscuits of the shops may be used in this condition.

Milk is less constipating if it has not been skimmed, the fat of the cream being laxative. One of the best aperients for babies is cream.

Bacon cooked until crisp and dry is serviceable, by reason of the fat of which it is composed.

Butter, in large quantities upon gluten, bran, or brown bread, will be of service. Oils, with green vegetables may be used.

When the condition is the result of dyspepsia, it is important to avoid making any pronounced change in the diet without giving a due consideration to the digestibility of the food selected; as woody vegetables, so serviceable in constipation, are very difficult of digestion. Certain cases are benefitted by the use of inert substances which by reason of their bulk stimulate peristalsis. Among these are agar-agar and liquid paraffin.

Acute diarrhea is to be treated according to the cause which occasioned it. If an irritating substance has been ingested or developed, the withholding of all food for a time after the irritant has been expelled will prove the best initial treatment.

Albumin water is serviceable. Boiled milk, skimmed milk, or milk to which flour has been added and boiled (making the preparation known as "pap"), will prove acceptable. Brown-flour soup, "gebrannte Mehlsuppe" of the Germans, with or without ginger or other acceptable spice, is highly regarded, while beef scraped or the pulp prepared by pounding the beef in a mortar with water or milk and then strained, is to be given. The latter preparation may be peptonized.

Chronic Diarrhea.—The condition with which the diarrhea is associated will influence the dietetic treatment. The food should be administered in small quantities and at frequent intervals. Fermentable foods, and those likely to excite diarrhea, are to be avoided. Chicken and game meats are to be considered in this class. It is important that the intestines shall be spared every effort, as far as possible, to digest and assimilate the food administered. This means that egg albumin, skimmed milk, buttermilk, sterile beeftea, beef juice, and scraped meat should form the chief constituents of the diet. Koumys, zoolak, cottage cheese, and certain of the manufactured foods are also available. If judiciously administered, these articles will prove an acceptable diet for a protracted period.

When the digestive power increases dextrinized bread or flour soup, cream of potatoes, corn starch, and "pap" may be given. Farina gruels combined with whites of eggs are suitable to these cases. Brandy and red astringent wines, such as Burgundy or claret, will be serviceable in certain cases.

Dysentery.—The acute and chronic forms require those foods which are completely digested and leave a minimum residue.

Egg albumin, sterile beeftea, beef juice, scraped beef, gelatin foods, skimmed milk, and milk fortified by the addition of albumin, curds and whey, grated cheese koumys, and similar foods are to be considered the chief articles of diet. The return to a diet containing starch, sugar, and fats should be long deferred and cautious.

Intestinal Diseases of Childhood.—It is possible to consider a large group of separate conditions under this heading. In all of them the limit of bacterial invasion consistent with health has been passed. In the successful treatment of these cases the first requisite is to secure the closest possible approach to a favorable flora of the gastrointestinal tract and to introduce no food that will carry reinfection or yield a favorable medium for the development of pernicious forms of bacterial life. In marked contrast with the conditions we strive to prevent are the favorable results that may be secured by cultivating a prolific growth of the Bulgarian lactic acid bacilli. This is accomplished by clearing out the gastrointestinal tract with castor oil or Epsom salts. Only water or barley water should be given during the subsequent twenty-four hours. The following day milk, suitably diluted, is administered and a tablet containing cultures of these bacilli is given before and after each feeding. Constipation, vomiting and malnutrition yield with surprising frequency to this method.

Condensed buttermilk, suitably diluted, will give good results in many of these cases. It may not be continued for a protracted period and its use offers no advantages over the method where the tablets are employed. These diseases are usually associated with an inability to readily digest the casein constituent of milk, and this inability manifests itself by the occurrence of colic soon after taking food and by the presence of curds of varying sizes in the evacua-

tion. The casein should be lessened by the dilution of the milk with water or other diluent. In those cases in which there is a total inability to digest casein, whey will be found acceptable. Albumin water is in favor in these conditions. Partial peptonizing may enable the patient to digest ordinary milk. The simple dilution of the milk lessens the proportion of sugar, and, thus, the likelihood of fermentative changes and acid stools is lessened.

The fat of the milk is likely to favor diarrhea and vomiting. Skimmed or boiled milk will be indicated in those cases in which there is reason to believe that the patient is unable to digest the fat. The advantage of a temporary withholding of food is not to be forgotten. Beef juice diluted with warm water, mutton broth, veal broth, or barley and egg water, will each be found serviceable. There is no dietetic regimen, just as there is no particular food that is adapted to every one of these cases. The food must be modified to meet what we conceive to be the existing condition and the digestive power of the parts involved.

Acute Appendicitis.—An acute attack of appendicitis demands a liquid diet. There should be no excessive residue; neither should there be so little residue as to favor the occurrence of constipation with the attendant likelihood of extension of the inflammatory process. Thus milk, toasted bread, freshly prepared broths, egg albumin, and gelatin preparations would yield a suitable dietary.

Ochsner advises an avoidance of purgation and the withholding of all food until the most acute symptoms have abated. The mouth may be moistened by sips of cold water and small amounts of very hot water may be swallowed. Gastric lavage is practised and, for persistent nausea, is repeated from every two to four hours. Debility is combated with enemata of concentrated liquid food. Eight ounces of normal salt solution may be given by the bowel four or six times a day if no liquid is being taken by the mouth. After the patient has been free from symptoms of the disease for four days he is given stimulating beef-tea. Peptonized food and milk are gradually introduced into the diet.

Chronic Appendicitis.—Foods which would yield a coarse bulky residue, and improperly cooked meats are to be avoided. Oatmeal as ordinarily prepared by being boiled for as short a time as half an hour is not suitable for food purposes. Cabbage, corn, and fruits containing seeds or having dense skins are to be omitted because of the tendency to induce intestinal indigestion and flatulency, and not because of the danger of their entering the appendix. Thus, the class of articles to be avoided constitutes the chief dietetic direction to be given to these patients. Overeating, gamey food, the ingestion of a large quantity of very cold food, ice cream, or beer may aggravate the disease. The diet should be a simple mixed one containing no elements likely to tax digestion or to favor the development of intestinal catarrh. Thus, the legumes represented by peas, beans, and lentils with dense skins and sulphur as a constituent are objectionable. Corn is more likely to do harm in these cases than is cornlet or cornmeal. Pickles, onions, and highly seasoned condiments are of questionable utility.

Jaundice, Biliary Calculi, and Cirrhosis of the Liver.—In the dietetic treatment of these conditions sugar is to be eliminated as far as possible from the food. Starches are to be reduced to a minimum because of their change into sugar in the course of the process of digestion. So far as possible it is well to administer starches only in moderation and those combined with gluten, *e.g.* macaroni, vermicelli, and rolled wheat. Rice, tapioca, sago, and arrowroot may be given. Potatoes are permissible if given in moderation, but the vegetables poor in starch are to be preferred. Cream soups, spinach, celery, lentils, peas and beans are of value in these cases. Fruits of the subacid variety are permissible, as apples and oranges.

Milk is allowable, but should be thoroughly skimmed to exclude the fat, and diluted to reduce the curd. Some objection has been made to the use of milk because of its sugar. The sugar of milk is less objectionable, however, than the cane sugar and need not to be so rigidly excluded from the diet. The use of butter is to be curtailed or entirely omitted. The white of egg prepared in various ways will furnish the proteins required for food purposes, but the yolk is objectionable.

Fish, particularly the white fish, may be given; the oily varieties represented by mackerel, eels, and herring are to be avoided. Meat in the morning is permissible.

If wines are demanded the sweet ones should be avoided, and extra dry champagne or Moselle wine should be selected.

Acute Nephritis.—The ideal food is milk. In truth it seems to be the only food suitable to this condition, and it becomes a question of the method of administration of milk rather than of the selection of a dietary (see section on Milk).

For the sake of variety, when the patient rebels against a milk diet, some one of the waters prepared from the cereals may be given. The carbonated waters are serviceable in these cases. A departure from the exclusive milk diet should be regulated by the condition of the urine. The starchy foods are to be added to the diet gradually, and, if no untoward effect is produced, the lighter meats may be cautiously added. von Noorden recommends the reduction of all food to as little as a pint of milk in twenty-four hours in cases of increasing edema. Diaphoresis should be induced and whiskey or brandy given to meet the needs of the circulation. When this limited diet can no longer be persisted in or the condition improves, the calorie value of the food should be increased by the addition of cream, rice, cornmeal, oatmeal, crackers and zwieback. Cream of tartar lemonade is of service as a beverage.

Chronic Parenchymatous Nephritis.—One of the greatest dangers for these patients is the appetite. The protracted privation of ordinary foods seems to make the appetite more voracious. "The good results of the milk treatment in cases of chronic nephritis is now among the best acknowledged in the treatment of the malady, as evidenced in the diminution of albumin, decline in dropsy, increase in the quantity of urine passed, and general amelioration of symptoms." (Tyson's "Practice of Medicine.") These patients should take from five to nine pints of milk in the twenty-four hours, according to the amount of energy expended. When the fullest measure of benefit obtainable from an exclusive milk diet has been attained the quantity administered may be lessened, and starches cautiously introduced to compensate for the deficiency of this constituent absent from the milk diet. Protein in the form of meat and eggs is not so rigorously excluded from the diet as it formerly was. Indeed, it has a recognized advantage in selected cases. These must be determined by noting their effects upon metabolism.

Salt-free diet is most advantageous in cases complicated by edema. In certain instances it yields results unattainable by any other procedure.

Chronic Interstitial Nephritis.—Here, as in other forms of nephritis, a milk diet is the one that yields the most satisfactory results. Fortunately, the range of combinations with other foods is not so limited as in the cases previously considered. To maintain a condition of metabolic equilibrium is of prime importance, even if there should result a moderate increase in the percentage of albumin in the urine. Since meats are so closely associated with the development of complications in these cases, it is to be remembered that a uric-acid-free diet can be

obtained by securing the nitrogenous constituent necessary for a complete food from milk and cheese. All forms of alcohol are to be curtailed or entirely eliminated. Too much water may prove disastrous by taxing the circulatory mechanism. A restriction of the salt intake will lessen the desire for water.

The possibilities of a meat-free diet are great and promise most in these cases. The advantage of having the diet composed of few articles in the proper proportion is well illustrated in these cases, in which it is necessary to note the effect produced by various food combinations.

Uremia.—The diet suitable to a case of acute nephritis, as indicated above, will be found to be best adapted to cases of uremia. Skimmed milk is the form best adapted to these cases.

Circulatory Diseases.—The success of all dietetic measures is dependent upon the integrity of the circulatory mechanism. The activity of the digestive juices is determined by the character of the circulatory fluids of the body; the functions of all of the organs of the body are influenced by the character and the quantity of the blood they receive; the metabolism, absorption, and nutrition of all of the tissues are proportionate to the completeness with which the heart, the vessels, and the blood perform their physiological functions. It is the intimate interdependence of the various functions that explains the constant association of certain symptoms, *e.g.* the dyspepsia, indigestion, palpitation, and constipation, which are associated with anemia. It is in this manner that morbid states are perpetuated. Dropsy results from watery blood, transudation of the liquid element of the blood being favored by a condition of hydremia; and this condition is the result of deficient nutritive elements. It is not possible to continue for a protracted period a dietary unsuited to the kind of work being performed. Certain cases may be saved by a dry diet; others must have liquid nourishment.

Anemia.—The form of this disease most frequently met is that associated with the period of puberty in girls. At this time growth and development are more active than previously. The nervous system is actively concerned in this transitional state and doubtless exercises a determining influence in the early manifestation of digestive involvement. The intake of food after the condition is established is unsuited in character and quantity for the constructive needs of the system at this time. The excessive consumption of the nitrogenous elements is evidenced in the increased quantity of urea eliminated. The inclination of the patient is to sweets and starches, if an actual perversion of taste does not exist. In all cases in which there is a departure from the normal composition of the blood the same dietetic rules will be found serviceable. The condition essential to a normal blood supply is that sufficient food be taken, digested, and assimilated. With food as with the administration of iron in this condition, the question is not so much how great an amount may be taken as how best to secure the assimilation of the largest possible quantities. A diet deficient in proteins has been found constantly associated with a hydremic condition of the blood. It would, therefore, seem to be of prime importance to prescribe in these cases a diet containing the largest possible quantity of protein food. In the severer forms it will be necessary to peptonize the food and to give small quantities at frequent intervals. Milk and meat are the foods most suited to meet the requirements, and they are the forms of nourishment likely to be most distasteful to the patient. It, therefore, becomes a question of presenting them in the forms least objectionable. Scraped meat cakes, meat powder and broths, pounded meat, bone-marrow soup or sandwiches, or sandwiches of gluten or whole-wheat bread with dry crisp bacon, lettuce and mayonnaise dressing, chopped meat with celery, pine nuts, or almonds, offer attractive combinations for the administration of meat. Cheese combined with Italian pastes, macaroni, vermicelli, or noodles, or with potatoes, yields the desired nitrogenous element. Fats seem to be especially helpful in curing this condition, and by the liberal use of cream prepared in an acceptable way, or of butter and whole-wheat bread, or by the administration of small doses of cod-liver oil, we are able to secure fats in an assimilable form. Creams of the nitrogen- and iron containing vegetables are not to be neglected. It is held by some that the iron in combination with vegetables is the most assimilable form. Thus we should use carrots, beets, spinach, peas, beans, lentils, and gluten meals.

Laryngitis, Tracheitis, and Bronchitis.—The diet adapted to any acute febrile process will be suitable to these conditions, and will be discussed under that heading.

Asthma.—The importance of dietetic measures cannot be overestimated in the treatment of this condition. The proper preparation of the food and of the stomach for its reception, combined with the adjustment of the food to the work being performed, will give results justifying the care exercised.

Hot water should be given an hour before meals, and at bedtime. In certain instances the addition of bicarbonate of soda and essence of peppermint will give good results.

Breakfast should be composed of eggs with dextrinized bread, creamed chipped beef, fresh or smoked fish; a cereal with a liberal supply of milk, *e.g.* a pint, and little or no sugar, may prove an acceptable meal.

Dinner, which should be taken at noon, may consist of a clear soup, or cream of potatoes or similar nutritious vegetable; macaroni and cheese, or some form of meats furnishing the nitrogenous element. The starchy food should be confined to one vegetable, and it may be steamed rice, a small potato, or spinach after it has been passed through the colander. Junket, corn starch, or apple tapioca may be eaten as dessert.

For supper milk, milk jelly, Bartholow's food, or a cereal will be suitable. If the patient is expending considerable energy, some cold boiled ham, tongue, or sardines may be allowed.

Beverages.—It is best to withhold the use of tea and coffee and reserve the therapeutic effect of these beverages for the favorable influence they exercise on the paroxysm. Water is not to be taken with meals except in the smallest quantities.

Fatty, fermentable, bulky foods are to be avoided. Should the case present an excess of uric acid in the urine, the diet should be confined to "uric-acid-free" substances. In so many instances the paroxysms occur on Sunday night, that one is forced to recognize the probability of the increased intake of food and the diminished expenditure of force on that day as bearing a causal relationship to the development of these attacks. These patients may take the following foods: White meat of fish and chicken, beef soup, scraped, pounded, or chopped beef, eggs slightly cooked, green vegetables free from oxalates, coffee, and water in moderation. The carbohydrates should be confined to one variety with any one meal, and this one should be a form of easily digested starch.

Asthmatic patients should avoid coarse fermentable foods—indeed, an excess of any kind of food; fats should be avoided, or taken in the form of butter. Malt liquors should not be taken.

Pneumonia.—In this disease the diet suited to an acute fever is indicated.

In the puny youth, or decrepit old patient, the nutritive worth of the milk may have to be increased by combining with it strained gruels of arrowroot, barley, oatmeal, or corn starch.

Pleurisy with Effusion.—"A dry diet" suggests the object sought in the effort to influence this condition by means of food. The amount of fever present will determine the extent to which the exclusion of liquids may be pushed. A diet made up largely of scraped beef, minced chicken, cereal foods, cheese, macaroni, vermicelli, curds and toasted bread, will favor most the absorption of the exudate, and should be employed, if not contraindicated by other conditions present. Vegetables containing a large percentage of water, such as potatoes, beets, tomatoes, etc., are objectionable.

Pulmonary Tuberculosis.—The diet should be adapted respectively to each one of the three periods of the disease.

In the first stage any combination of foods that will bring the patient to a higher nutritive level, giving most fat and a corresponding improvement in the blood with a minimum expenditure of energy in digesting the food, is best suited to the condition.

Forced feeding—made possible by the use of bitter tonics or the employment of a stomach tube—is to be employed so long as it does not excite gastric catarrh. Fats are of prime importance, and may be given in various forms; for example, butter, thickly spread upon gluten or whole-wheat bread or biscuit, or upon meats, and in every possible form; cream in as large quantities as can be digested; fat of roasted or of broiled meats; and meats containing large quantities of fat, *e.g.* game and squabs.

Milk, if sound, is second to no other food in these cases. It should be given in every possible form—whole, skimmed, buttermilk, koumys, matzoon, zoolak, cottage cheese, cream cheese, junket, bonny-clabber, puddings, and in every possible combination that may prove palatable.

Red and dark meats are preferred because the fat is contained between the fibers, and is more accessible than when it forms a separate layer, as in the case of white meats. Roasts, steaks, chops, beef chopped, scraped, or pounded, beef juice or nutritive beeftea, beef with minced celery, or with pine nuts, onions, or other seasoning to stimulate digestion and aid nutrition, are of the utmost value.

Eggs in any one of the five hundred ways in which they may be prepared are of especial value. The large percentage of fat contained in the yolk, and the easy digestibility of the albumin, make them an important food. The dried white of egg may be added to broths and soups, and, in this way, a large number of eggs may be consumed in a day.

The cereals and more easily digested forms of starch are best suited to furnish the carbohydrate element of the food. Fermentable foods, as hot bread, starches, and pastry are to be avoided. Malt extracts are serviceable as aids to digestion. There are numerous "diet cures" for tuberculosis and, as in most instances, the multiplicity proves the inefficiency of any one system.

In the second stage of the disease the same dietary will be suitable, if care is taken to restrict the food requiring the most active digestive processes to the periods when the patient has the least fever. Regard must also be paid to the catarrhal condition of the digestive tract so often present in these cases.

In the third stage of tuberculosis the food must be confined to the articles that yield most nutrition and tax the digestion least. There are numerous instances in which patients with advanced tuberculosis eat excessive quantities of the foods least adapted to their condition with apparent impunity. There is no food that will do more to prolong the life of these cases than egg albumin in large quantities. It seems to act as pine shavings to a nearly extinct fire. The objection that holds against the administration of alcoholic beverages in the earlier stages of the disease does not apply to patients at this period. Whiskey and brandy, judiciously administered, are of positive value.

Acute Infectious Diseases.—Graves secured immortality by the request that "He fed fevers" should be his epitaph. The careful adjustment of food to the febrile condition would be a better reason for grateful remembrance. There can be no doubt but that much harm may be done by allowing a too extensive dietary to fever patients. It is only by keeping in mind certain well-established conditions that we are enabled properly to appreciate the dietetic indications.

The child or youth must have a larger amount of protein in the diet than the matured individual.

There are no data to enable us to determine the calorie food requirements as a result of a febrile process. It is estimated that an increase of 25 per cent. in the calorie worth of the food will approximate the need resulting from a fever of moderate severity. Thus if 2,500 calories were estimated as the diet suitable for a given case, a diet of 3,000 calories would be required during fever.

1. *In fever there is excessive destruction of the fluids and tissues of the body.*

(*a*) The loss of protein is greatest. It is indicated in the increased excretion of urea, and is measured by the muscular wasting and debility.

(*b*) The destruction of fat is evidenced by the emaciation.

(*c*) There are marked changes in the composition and quantity of the liquid elements of the body.

2. *The digestive and assimilative processes are perverted.*

(*a*) Gastric digestion, which is chiefly concerned in the utilization of protein, and to a minor degree of the fatty foods, is usually the function most seriously involved.

(*b*) Intestinal digestion is less perverted, and the carbohydrates and fats are more available for food purposes, provided they are given in liquid form. They are completely metabolized, leaving no residue, as is the case with protein food.

There is, therefore, need to adjust the dietary with reference to the affected part, and—according to our estimate of the ability of these respective parts to perform their functions—to give foods which require either chiefly a gastric digestion or chiefly an intestinal digestion.

The excessive destruction of protein tissue, with the attendant increase in the urea to be eliminated, should make us watchful that there is no failure to excrete these products of nitrogenous waste.

3. *Adjustment of food to the existing conditions.*

(*a*) The food should be fluid; solid food frequently excites nausea and vomiting.

(*b*) It should be sufficient to equalize a part of the combustion coincident with the fever. This may be accomplished by supplying:

(α) Protein food in the form of milk, meat broth, or egg albumin.

(β) Carbohydrate in the form of strained gruel, toast, barley water, or some similar diluent and nutritive liquid.

(γ) Fat must not be given in greater quantities than is present in the cream of whole milk.

There are two conditions constantly present in febrile processes: first, increased combustion, and second, diminished assimilation.

When the excessive quantity of food required to furnish heat for one degree of bodily temperature is taken into consideration, it is manifest that we cannot hope to give sufficient food to compensate for the destruction of tissue resulting from the febrile process. Our aim should therefore be to give nourishment in a form that will tax least the enfeebled digestive organs, and that may be most readily assimilated.

The digestive juices are scantiest when the fever is highest, therefore adjust the administration of the most nutritive food to the time when the temperature is nearest normal, *e.g.* in the morning and at noon,

in a case of tuberculosis. The selection of food will be influenced by:

1. The age of the patient. For puny, badly nourished children and feeble, aged patients, a persistent effort must be made to maintain the strength of the patient.

2. The severity of the fever. An acute self-limiting fever in a robust individual warrants less anxiety, and less urgently demands the ingestion of a considerable quantity of nourishment. A high temperature for a protracted period demands a commensurate intake of nutriment.

3. The condition of the digestive and excretory organs. The diet should be entirely liquid, or semi-solid, according to the estimated condition of the digestive functions. In the exanthematous diseases, in which the kidneys may become acutely involved, an exclusive milk diet should be instituted.

Milk must be given first place as the food suitable for nourishing the sick. The curd must be modified by means of some of the methods previously indicated. The taste and digestibility may be changed by the addition of aromatics and malt extracts. The nutritive worth may be increased by the addition of egg albumin and carbohydrates, which should be given cool or warm according to the preference of the patient. It may prove more acceptable to the taste, and more easily digested, if taken through a tube. The milk intended for the patient should be kept separate from that used for other purposes, so that the quantity used in a day may be accurately determined. The evacuations should be studied to detect any evidences of failure to digest the fat or casein of the milk.

Meat should be given in a form that will prove acceptable to the patient. Clear bouillon, nutritive beeftea, beef juice, or scraped beef must be selected according to the patient's taste and digestive power, and the stage of the fever.

Eggs will be found most valuable if only the whites are used. The yolks, however, are of service when convalescence is established and can be digested. They should be slightly cooked at a temperature not exceeding 180° F.

Gelatin preparations are regarded as "albumin-sparing foods," and may be secured in the form of gelatin, blanc mange, bromangelon, calf's-foot jelly, chicken jelly, wine jelly, milk jelly, and similar preparations.

In those cases in which a carbohydrate is desired, a strained cream of potatoes, peas, beans, asparagus, and similar vegetables may be employed. Cereals and light puddings or custards may be used.

Beverages.—First and of greatest importance is water, given in the largest quantity possible without exciting nausea. If there is irritability of the stomach, a simple carbonated water, or one combined with cracked ice and a few drops of brandy, may be found superior to champagne in allaying the nausea. Lemonade, prepared by using boiling water and straining after it has cooled, will be accepted by certain patients who cannot take it when prepared in the ordinary way. Dilute phosphoric or hydrochloric acid will be well received in some cases. The use of egg, barley, rice, oatmeal, corn, toast, and similar waters, will each in turn be found of utility. Tea and coffee, without sugar or cream, are not used as often as they might be in cases in which the contained alkaloids would not be objectionable. They have the additional advantage of possessing distinct therapeutic properties.

Alcoholic liquors are to be used only when a positive indication for them exists. They are valuable as foods and beverages, and require the minimum degree of effort upon the part of the digestive organs to utilize them. But they are not to be administered in doses larger than may be required to produce an odor in the breath some time after their ingestion. So long as the feebleness, restlessness, or sleeplessness is favorably influenced by their use, we may know they are doing good. The form in which they are exhibited is less important than is the purity of the beverage and the effect produced. In America whiskey is most used. All forms of alcoholic stimulants are less used than formerly.

Typhoid Fever.—The dietetic treatment of this disease may well serve as a criterion to guide us in the effort to select a suitable regimen for most of the febrile affections. There would seem to be two lines of dietetic procedure. Those who champion the high calorie diet and those who cling to an exclusive milk diet. Those advocating the high calorie diet recommend that as many as from 4,000 to 6,000 calories be given a fever patient. Those who cling to a strict milk diet must recognize that, in the customary three or four pints of milk given, the patient cannot receive more than from 1,000 to 1,400 calories. This is manifestly an insufficient amount. The emaciated, starved, convalescent typhoid patient who has been upon this strict diet is at last securing a long deferred recognition of the need of a more nearly sufficient diet for these cases. The protracted enfeeblement of every tissue of the body thus fed is in marked contrast with the patient who has been upon the high calorie diet throughout the disease. The difference in the mortality in the two classes of cases is in favor of the high calorie diet, but it is not as striking as might reasonably be expected. It would be instructive if some accurate estimate could be made which would contrast the return to normal efficiency of the patients representing the two lines of treatment. It is a safe assumption that there is now a marked disposition to feed typhoid fever patients a decidedly higher calorie diet than has previously been in vogue. It is too soon to adopt unreservedly the extreme views advanced by some advocates of high calorie feeding. Those who employ an exclusive milk diet throughout the febrile period, usually continue its administration until the temperature has been normal for one week. After this time they gradually introduce into the diet other foods. Milk is, without question, the food best suited to these cases. This is true for the following reasons: (1) It is a complete and sufficient food; (2) it is most easily digested and assimilated; (3) it is acceptable to almost all patients; (4) it is available, and its purity is easily determined; (5) it is easily modified as to taste, curd, and proportion of any constituent; (6) the dosage is easily regulated; (7) it furnishes a food which is both diuretic and diluent.

The somewhat prevalent idea that a considerable number of patients cannot digest milk is not founded upon fact, the difficulty being due rather to individual peculiarity of taste than to inability to digest the milk. The cases of illness in which milk cannot be made the exclusive diet, if the patient is so inclined, must be rare. The milk may be made more acceptable by modifying the taste and curd, by diluting to the extent of one part of milk to four of water, by feeding through a tube or giving a teaspoonful every minute for eight minutes of each hour, by having the patient take it from a porcelain drinking-cup and preceding and following it with a tongue bath. If, after persistent efforts of this sort, the patient is still unable or unwilling to take milk, it may be necessary to give it as whey or junket, or it may be peptonized, or sufficient oyster or clam juice may be added to it to impart a distinctive flavor. The failure of the foregoing methods for the administration of milk may necessitate the employment of nutritive beeftea, or manufactured beef preparations, the precaution being taken to ascertain that they possess protein worth.

Egg water, prepared by adding eight ounces of water to the white of one egg, is serviceable. Sherry, or lemon peel, or orange juice may be added to impart flavor.

The quantity of milk to be given to a patient must be determined for each particular case. Ordinarily, three pints in twenty-four hours is regarded as sufficient for the adult who is confined to bed with an acute illness of brief duration. If the patient is given six ounces of milk every two hours, from 7 A. M. to 7 P. M., and two feedings of six ounces each during the night, he will receive three pints in twenty-four hours; or if eight ounces be given every three hours during the day, and twice during the night, the same amount will be ingested. This plan insures the administration of the quantity determined upon as desirable. The calorie value of milk can readily be enhanced by the addition of cream. Water should be introduced in the largest possible quantities short of producing discomfort, nausea, or unduly increasing the liquid element of the blood. It should be urged upon the patient regardless of his disinclination to take it. The abatement of toxemia coincident with increased renal and cutaneous elimination is an almost constant experience.

A reference to the table of calorie values of individual portions will find simplified the problem of estimating the worth of the diet ordered.

The mouth toilet, represented by correction of an unhealthy condition of the gums and teeth and a tongue bath will go far toward preventing infection of the food and consequent gastrointestinal derangement.

The evacuations should be watched, and the presence of curds or globules of oil would demand respectively either the lessening of the quantity of milk, or the rendering of the curds smaller, and diminishing the quantity of cream contained in the milk.

Constipation will be less annoying if large quantities, *i.e.* five pints or more, of water are given daily.

Hemorrhage, or perforation, will make it advisable to withhold all food or give meat juice, a half ounce every hour or two, or gelatine. Opium sufficient to check peristalsis is indicated. Give meat juice only; a half ounce may be given every hour or two. Six ounces of meat juice represent the liquid element of one pound of beef. The beef juice is speedily absorbed, and leaves so little residue that there is no need to have a bowel movement until a sufficient time has elasped for the bleeding point to have healed.

If we remember that the stomach is the first to recover its function, and that it has been least involved in the morbid process, we shall appreciate the fact that the dietetic indication is to give foods requiring gastric rather than intestinal digestion. Those who adhere to a strict milk diet during the fever, usually make it a rule to give a milk diet until the temperature has been normal for one week, then to give the whites of eggs raw or slightly cooked. Foods such as chicken jelly, junket, pap, an entire egg, strained cream of potatoes, oysters and clams, raw oysters, ice cream, cornstarch, arrowroot, egg custard, scraped beef, baked potatoes, and similar *properly prepared* good food, should constitute the diet for at least a month after the temperature has been normal.

Acute Articular Rheumatism.—The food suitable for any acute febrile process will be acceptable in this disease. Milk foods and cereals in the form of broths are to be given. After the fever has subsided a greater variety of broths and light custards may be given. It is preferable to secure the nitrogenous elements of the food for these cases from a vegetable source, unless it can be given in the form of casein. Broths of oysters and clams, rice or barley soup with chicken, or egg prepared in digestible forms, may be administered, unless they excite some untoward symptoms.

Chronic Articular Rheumatism.—The conditions demanding dietetic considerations are similar to those present in gout, and the diet outlined for that disease will serve in this instance (see the following section).

Gout.—Under this head are included Lithemia, Uric-acidemia. Gout is regarded as dependent upon a deficiency of one or more of the enzymes concerned in purin metabolism. The frequency with which attacks of gout follow indigestion would emphasize the need of omitting all foods or food combinations that have been found to cause dyspepsia in particular individuals.

von Noorden recommends that the purin tolerance of these cases should be determined and made the basis of the diet allowed. To this end he places the patient upon a purin-free diet and estimates the endogenous uric acid in the urine. He then adds beef to the diet, and after making allowance for the percentage of normal endogenous purin metabolism, he estimates the degree of retardation of purin elimination. The allowance of protein foods is regulated according to the determined ability of the patient to metabolize them.

The following table abstracted from Walker Hall's "The Purin Bodies of Food Stuffs," shows the amount of purin bodies in various food materials:

Tripe	.0572
Loin of veal	.1162
Loin of pork	.1212
Neck of pork	.0567
Ham	.1155
Ribs of beef	.1137
Sirloin of beef	.1305
Liver	.2752
Thymus (sweetbread)	1.0063
Chicken	.1295
Turkey	.1260
Rabbit	.0970
Oatmeal	.0530
Pearneal	.0390
Beans	.0637
Lentils	.0637
Potatoes	.0020
Asparagus (cooked)	.0215

Gallstones.—The dietetic treatment is seldom instituted until their troublesome presence has rendered its employment of small service. The factors regarded as potent in their formation give the indication for a suitable diet. These are anything that favors concentration and stasis of the bile, such as the too restricted use of water, sedentary habits, and all factors that favor indigestion. High game, fish and oysters that are not strictly fresh, odorous cheese, heavy puddings, fats and pastry are held to be particularly objectionable. The results from the administration of olive oil as a cure have not justified the expectations entertained. It is quite generally conceded that fats are objectionable in most forms of liver disease. To promote a more continuous flow of bile, food in small quantities should be given at frequent intervals and water drinking between meals should be encouraged. Frequent feeding may do harm in cases complicated with atonic dyspepsia. A suitable diet should comprise protein and carbohydrate combined in simple, well cooked dishes and in moderate quantity. A diet made up largely of buttermilk and finely mashed spinach often gives good results.

Without entering into a consideration of the identity of the pathology of these diseases, it may be confidently asserted that the dietetic treatment for all is so similar that they may be considered at the same time. It is well to remember in this connection that in these cases "there is a want of balance between the intake of food and the power of the body to oxidize and utilize it." Here, as in so many conditions, the disease is not limited to one organ, but is the result of an inability of all organs concerned in food elaboration. The end product of the digestion of purin-containing foods in these cases is uric acid, which is decidedly less soluble than the urea which should be the form in which the excretion occurs. The indication in these cases is to administer the foods poor in purin bodies.

Ready and complete digestibility and assimilability of the food administered must also be given consideration. Moderation is a watchword for all these cases. The food must be adjusted to the age and occupation of the individual. A vegetable diet is one most favorable to these conditions, and yet it would be a serious mistake suddenly to change the dietary of an individual from one made up chiefly of meat to one entirely composed of vegetables. It would be still more disastrous to attempt to make vegetarians of all of these patients. An intelligent adjustment of the various food elements, as to both the quantities and the food combinations will give the best results. Since the conditions under consideration are in a great measure expressions of disturbances of purin metabolism, it is well to keep in mind that we have purin derived from the nuclei of the body cells (endogenous) as well as from the protein food (exogenous) ingested.

There is great need of a more extensive and accurate study of the causal relationship existing between food and the conditions conveniently grouped under the designation "lithemia." Two propositions that seem almost axiomatic may, however, be stated: first, most individuals eat too much food, and second, most Americans eat too much meat. It is surprising what a small amount of food will prove sufficient for the demand of the system after maturity has been attained. A close adherence to the rule that permits enough food to satisfy positive hunger and no more is the price of comfort for many lithemia patients. Fothergill expresses this idea when he says, "there is no nice way of having gout, and what is worse, there is no pleasant way of avoiding it."

The dietetic treatment will have to be adapted to the stage of the disease. During the acute manifestation of the disease none but the lightest nourishment should be given. Diluent, diuretic, and diaphoretic drinks, milk diluted with carbonated water, thin gruels, or similar preparations, should be given. Hot drinks are indicated.

The interval between the acute manifestations offers the most favorable opportunity for influencing the disease. The greater facility with which we secure complete metabolism of a meal composed of one or two simple foods, selected with a view of securing a complete food, would make it advisable to adopt this method in arranging the dietary for these cases. The plan pursued in the meal composed of several courses is intended to stimulate the appetite, with the result that the digestive and assimilative powers of the individual are frequently overwhelmed with uric acid, which the organs concerned are unable to excrete, and an acute paroxysm of gout results. The nitrogenous element of the food for these cases may be derived from whole milk rather than from skimmed milk, which contains a larger percentage of albuminoid. If whole milk cannot be digested, it is better that it should be diluted with alkaline water than to have it skimmed. The fat contained in the cream is of service in lessening the amount of carbohydrate that would otherwise be required. Milk is of further advantage from the fact that it will not yield uric acid.

In those instances in which a meat-free diet is not to be insisted upon, oysters and clams may be used in a great variety of ways, and their preparation enables us to introduce large quantities of milk and water into the system. Fish of almost any variety, excepting the indigestible forms, represented by those containing a large percentage of oil—*e.g.* mackerel, herring, eels—are permissible.

The meat of fowls may be prepared in a great variety of ways, ranging from broths to the minced meat made into panada, or, if the digestive power will permit, it may be given roasted, broiled, or stewed.

Eggs slightly cooked may be used, and if they are found unsuited as food for these cases, it will probably be the yolk that has disagreed, because of the large amount of fat contained in it. The albumin of the white is very easily digested.

Cheese, representing the albuminous and in some instances the fat constituent of milk, has many of the advantages possessed by milk as a food and ought to be used to furnish the albuminous element of the meal. There is less likely to be indigestion from its use if meat is excluded from the meal, of which cheese is to furnish the nitrogenous element. The constipation so frequently associated with the diet into which cheese enters is less troublesome if cream cheeses are taken. The ability to digest different varieties of cheeses varies with the individual patients. Sometimes it is necessary to begin the use of cheese in the dietary by administering casein in the form of junket, then cottage cheese, Neufchâtel, or some similar cheese rich in cream. It not infrequently requires time and persistent effort before it can become a considerable element in the dietary of certain individuals. If we desired to give a cheese poor in fat and rich in casein, we should select the Parmesan cheese. This variety may be added to broths, after it has been grated, to increase their nutritive worth, or it may be made into sandwiches, and if whole wheat or gluten bread be used, there will be secured in such a combination a food containing a large nitrogenous element. Cottage cheese because of its digestibility and nutritive value should be used more extensively. Cheese, according to the variety selected, is said to be two or three times as nutritious as meat. One has only to remember how largely this form of food takes the place of meat in almost every country except America, and to contrast the infrequent use of it in this rôle, to realize to what great extent meat enters into the dietary of the Americans.

Fats, in moderation, serve a useful purpose in the dietary of these cases. Any evidence of inability to digest them may be regarded as a contraindication to their use.

Sugars, just as fats, are permissible to a limited extent. They must not be taken in quantities sufficient to excite indigestion or to favor the development of corpulency. So far as sugars and fats can be utilized as heat and force producers, they do good; more than sufficient for this purpose should not be ingested.

The vegetable element of the meal should be made up of one, or at most two, vegetables. If the nitrogen required is supplied in the form of meat, milk, or cheese, then the vegetable had better be one composed chiefly of starch, *e.g.* potatoes or rice. When peas or beans are used the contained nitrogen will furnish a portion of that required for the meal.

The green vegetables, so long as they do not excite indigestion by reason of their bulk and woody fiber, are allowable.

Cereals, when properly prepared and thoroughly insalivated, may form a part of the morning and evening meal. Oatmeal, because of the purin content, is sometimes objectionable.

Macaroni and vermicelli, arrowroot, corn starch, and bread, offer convenient and digestible forms of starchy food.

Fruits suitable to these cases must be neither too sweet nor too tart. Grapes and oranges are most often acceptable; strawberries are the most harmful.

All forms of food for these patients must be studied with reference to the effect produced on each case. The more nearly we accurately estimate the need and ability of a given case to metabolize various kinds and quantities of foods, the more likely we are to get satisfactory results.

Beverages.—Water stands first, and might with advantage be made the exclusive drink. Water, plain or medicated, hot or cold, should be used in large quantities to secure its mechanical and solvent effect upon the excretions. The most favorable time for its ingestion is a half-hour or an hour before, or several hours after a meal.

Tea, coffee, and cocoa are permissible, but cider, port, champagne, and malt beverages are not usually permissible. For those who require it, a light wine, poor in sugar and alcohol, if diluted with carbonated water, may be administered. Moselle, claret, or Hungarian wines are permissible.

If a spirituous liquor is required, whiskey, brandy, or gin, well diluted, may be given.

The foods prohibited are those containing oxalic acid in considerable amount, *e.g.* rhubarb, spinach, tomatoes, asparagus, sorrel, and radishes; neither must patients take spiced or dried meats, pork, bacon, veal, game, eels, mackerel, salmon, or lobster, or rich gravies, pastries, and candies.

Diabetes.—Failure to recognize the presence of the disease may result from neglect to examine the urine voided after the chief meal or from neglect to examine a specimen representing the entire daily output. There is a recognized periodic variability in the ability of the economy to metabolize sugar. This may result in a failure to recognize the presence of the disease until it is quite advanced.

The treatment of the disease may no longer be regarded as a simple dietetic procedure. A careful and systematic estimate must constantly be made to determine the amount of sugar being eliminated; the amount and composition of the food taken and the ability of the economy to metabolize the various forms of carbohydrate; the presence of ketone bodies represented by acetone, diacetic acid and oxybutyric acid and to determine the factor influencing the failure of digestion. There is no other disease in which the relation of diet to the activity of the morbid process is so intimate. Anything less than the most detailed attention to the ingestion of food, and the excretion of sugar in the urine, is an act of censurable neglect. It can be readily appreciated that the selection of alimentary substances is of no more importance than their proper preparation. A condition demanding, for a protracted period, a diet composed of articles from which an entire class of foods —*i.e.* carbohydrates—must be curtailed if not entirely eliminated requires the greatest skill and ingenuity on the part of the one to whom the preparation of the food is entrusted. It is not enough to hand to a patient suffering with this disease a list of the foods allowed and those to be omitted. Here, more than in any other condition requiring dietetic direction, is there need to demonstrate to the patient the possibilities of the curtailed regimen permitted him. There must be a thorough understanding between the doctor and the cook as to what is to be attempted, and that the starches and sugars are not to gain entrance into the dietary in any form. For instance, it would not be permitted to use wheat flour as a thickening in soups when we had forbidden wheat bread in order to eliminate starch.

Before beginning the dietetic treatment of this disease certain facts should be determined as a result of observations extending over several days. The quantity of urine voided and the percentage of sugar contained in it; the diet yielding these figures; the weight of the patient and his strength, as evidenced by tests with the dynamometer or graduated work; all require careful consideration. After this has been done the capacity of the organism to metabolize carbohydrates should be determined. The plan suggested by von Noorden, according to which the patient is gradually placed upon a standard diet, may be recommended.

von Noorden's Standard Diet.—After the carbohydrate element of the diet has been gradually eliminated the following diet is administered:

Breakfast: Tea, 5 grams infused in water 200 c.c.; ham, 150 grams; one egg.

Lunch: Cold roast beef, 200 grams; cucumber, 60 grams with vinegar 5 grams, olive oil 10 grams, salt and pepper (to season); Apollinaris water, 400 c.c. with brandy 20 c.c.; coffee, without milk or sugar.

Dinner: Clear boullion, 300 c.c.; beef, 250 grams; butter, 10 grams; green salad, 80 grams; vinegar, 10 grams, and olive oil, 20 grams; sardines, 3; Apollinaris, 400 c.c., with brandy, 20 c.c.

Supper: Two eggs; Seltzer water, 400 c.c.

This diet contains about 204 grams of albumin, 135 grams of fat, and no carbohydrate. It is to be continued until there is an absence of sugar from the urine in the one instance, or until it demonstrates the amount of sugar being formed despite the absence of carbohydrate in the food ingested. This method yields a basis for the classification of these cases, and is of further advantage in enabling us to determine the ability of the economy to metabolize varying amounts of carbohydrates in those cases in which there was an absence of sugar from the urine after the patient had been upon the "standard diet" for a sufficient length of time. A patient whose urine shows no sugar for several days as a result of the carbohydrate-free diet, is allowed some form of starch, in gradually increasing quantities, until sugar reappears in the urine. The following formula will then express his power to metabolize starch: tolerance to starch = standard diet + x grains of starch.

The gravity of the disease is proportionate to the amount of sugar persisting, notwithstanding the administration of the "standard diet." In the cases in which sugar appears in the urine despite this diet, we are given a measure of the transformation of the albuminoid tissues and fats into sugar. It is likely that transformation of proteids or fats into sugar occurs.

The indications in regulating the diet of diabetic patients.—In the withdrawal of the carbohydrates, the economy being denied the usual supply of carbon for the production of heat and force, it becomes necessary to supply a sufficient increase of fat for this purpose, and greatly to augment the intake of nitrogenous food for the same purpose. The dietary permissible to these patients includes all meats, excepting liver, which latter, because of its contained glycogen, is not suitable; and fats, which are called the sheet anchor by von Noorden, and which, in addition to their nutritive worth, are esteemed because they tend to produce a feeling of satiety, and thus relieve the distressing hunger so frequently a prominent symptom in these cases. They in a great measure supply the deficiency of carbon resulting from the withdrawal of the carbohydrate. The administration of fat requires the greatest care lest a disgust for it be excited. It can be introduced in the form of a thin layer rolled in a slice of roasted beef, or between bits of broiled beef; as a mayonnaise dressing on various salads; as butter spread very thickly upon almond biscuit or gluten bread; in the form of gravy of fowls; in the form of meats containing a large proportion of fat, *e.g.* mackerel, eels, blue fish, salmon, sardines, squab, and the dark meat of fowls; and ripe olives. Some writers also allow paté-de-foie-gras. The problem of successfully feeding a diabetic is largely one of skilfully administering in acceptable manner the various meats and fats. To these articles may be added a moderate allowance of green vegetables containing a minimum amount of starch, and possessing vegetable salts, the latter being of value for anti-scorbutic purposes.

Meats may be given in any readily digestible form, such as beef in the form of broth; scraped meat cakes suitably seasoned, to which may be added chopped almonds, pine nuts, or celery; cold boiled ham; crisp broiled bacon with eggs; chipped beef creamed, or as a sandwich with gluten crackers; tongue, kidneys, tripe, sweetbreads, calves' brains, smoked meats, and game of all kinds.

Fish of all kinds may be employed, as, for example, oysters, omitting the liver; clams, lobster, crabs; caviare, plain or combined with a few drops of grated

onion in the form of a sandwich of gluten bread or diabetic biscuit.

Milk is of service in certain cases, the sugar of milk being less likely than most other forms of sugar to favor the development of glycosuria. *Cream* is of especial utility, containing as it does an albuminoid and a fat. It may be given plain, combined with various flavors, whipped, frozen, or in conjunction with white of egg. *Skimmed milk* has been urged by various writers, large quantities, as much as from nine to twelve pints daily, being urged by Donkin, who reports favorable results from its use. He points out that in this form milk offers a concentrated assimilable albuminoid. Part of the milk recommended is to be taken in the form of coagulated casein. Koumys, zoolak, and buttermilk may be found acceptable and unobjectionable in certain instances.

Cheeses prepared from cream are less likely to increase the amount of sugar present than are those prepared from the whole milk. All forms of cheese may be utilized in certain instances.

Eggs offer an ideal food because of the albuminoid and large percentage of fat contained in the yolk. Given cooked or raw, with a little salt to facilitate their digestion, they lend themselves to innumerable methods of preparation, and may be consumed in large quantities.

Gelatin, if regarded as an "albumin-sparing food," should be of utility. It may be given in a great variety of ways, such as in the form of milk jelly, blanc mange, chicken jelly, calves'-foot jelly, and similar preparations.

The vegetables allowable comprise most of the greens; lettuce, cress, spinach, cabbage, asparagus, onions, cauliflower, cucumbers, dandelion; also cranberries, gherkins, artichokes, horseradish, kale, green French beans, pickles, carrots. Potatoes are allowed by some as a substitute for bread, because the percentage of starch contained is smaller than in ordinary bread. If potato be given in the form of a salad, with mayonnaise dressing and onion, or if it be baked and butter and egg added, it should possess special nutritive worth.

Fruits containing little sugar, preferably those containing it in the form of levulose, are permissible, *e.g.* apples, strawberries, gooseberries, currants, raspberries, sour oranges, and lemons.

Nuts of all kinds, excepting chestnuts, may form a large element in the dietary. They furnish a form of food that may be used extensively by varying the method of administration. If the patient picks the nuts from the shell he is apt to enjoy them more and is less likely to partake of them too freely. In other instances they may be administered after they have been ground in some one of the machines now upon the market for this purpose. This method of preparation overcomes the tendency to rancidity so pronounced in the nutmeals upon the market. Roasted and salted nuts are often particularly appetizing and sometimes aid digestion.

Forbidden Foods.—The forbidden foods comprise all saccharine or starchy vegetables and fruits, as well as the livers of animals and oysters. *Bread* is not permitted except in the milder cases, where it should be "torrefied" or twice baked.

Gluten bread is certain to contain not less than fifteen per cent. of starch, and usually the amount is much greater. It is heavy, and patients not infrequently refuse to eat it. It is well to learn the possibilities of the various manufacturers' products of biscuit of gluten, almond meal, and similar food substances which are likely to contain less starch than is contained in gluten bread; they are quite palatable and keep indefinitely.

The *sweetening* required is to be secured by the use of saccharin. This substance is likely to excite indigestion, and must be used in the smallest possible quantities. There are tablets on the market containing one grain of saccharin, which offer the substance in a convenient form. Glycerin is recommended for sweetening purposes by some writers.

Complications.—The development of acidosis may be recognized by a tendency to somnolence, a sweetish odor to the breath, and suitable tests applied to the urine. Here alkalies should be given by the mouth, rectum, or subcutaneously. Carbohydrate food is urgently indicated and fats and proteins are to be withdrawn or greatly reduced in the diet.

Oatmeal is recommended by von Noorden as one of the best foods in certain diabetic subjects who are threatened with acidosis. It is introduced in large quantities as the only carbohydrate, and the meat and fat are partially or entirely eliminated from the diet. There are certain cases, usually those verging upon acidosis, where its use is not attended with satisfactory results. He advises that the oatmeal be continued for one or two weeks.

Nephritis may so gravely complicate the disease as to make the adjustment of the diet for this condition take precedence.

Cures.—These are misnomers, but refer to assistance derived from the employment of certain articles of food giving the name to the cure. Best known among them is the oatmeal cure of von Noorden, the potato cure of Mosse, the yolk cure of Stern, and the milk cure espoused by many writers.

Beverages.—If alcoholic beverages are required because they have become essential to the patient, they should be confined to a dry or tart wine, such as Moselle, claret, nock, or Burgundy; brandy, whiskey, or gin may have to be given, and all beverages should be well diluted with an alkaline or carbonated water. Study the effects of particular wines upon a given case and regulate their administration accordingly.

Tea, Coffee, and Cocoa. Tea may be given, preferably with lemon; coffee, without milk or cream. Cocoa nibs and chocolate prepared without sugar may be used. The "*water cures*," notably those of Carlsbad, combine with the therapeutic effect of the water administered, a favorable environment, a suitable adjustment of food and exercise, medicated baths, massage, and an absence of the exciting causes that have been potent as factors in the production of the disease.

For one to whom so much is denied it is worth while to consider the possibilities of a daily ménu consisting of only the foods permissible. Such a dietary would comprise for one day:

Breakfast: Poached eggs and bacon; gluten bread; cream and hot water.

Luncheon: Cream of spinach; hot sardines on gluten biscuit, garnished with lemon and parsley; celery salad with mayonnaise; tea with lemon.

Dinner: Little Neck clams; consommé; roast beef; asparagus with melted butter; stewed onions; lettuce with French dressing; junket; coffee.

Nervous Affections.—Neuralgia has been defined as "the cry of a hungry nerve." The pain may be associated with the trifacial, gastric, hepatic, intestinal, or other nerves, and the neuralgia may be designated accordingly. If traumatic irritation has been excluded as an exciting cause of the condition, it is of importance to determine the degree of nutritional failure that is likely to be present in a particular instance. The intimate causal relationship between nerve pains and lithemia or uricacidemia, would lead one to endeavor to determine how far an excess of foods containing uric acid is concerned in the production of the neuralgia. Indeed, it would seem justifiable to regard neuralgia as a symptom; it may be of anemic, lithemic, gouty, rheumatic, or dyspeptic conditions, and these each, in turn, may be regarded as the products of faulty nutrition. Therefore the principles underlying the dietetic treatment of one condition will apply to all.

First, the habits of the individual must be studied. The food he has been accustomed to take, the care exercised in its preparation, the regularity in eating, and the suitability of the quantity and kind of food to the life work of the individual must be ascertained. A good practice in these, and in similar cases, is to have the patient continue, under observation, for a time without any dietetic restraint. Let a record of each meal be made and submitted for inr spection, and in this way it is often possible to discovea potent factor in the causation of a morbid condition. It is well, however, to guard lest a patient in moderate circumstances should bring a list of fare so sumptuous as at once to disprove its accuracy.

The study of the urine, with special reference to the amount of uric acid being excreted, will yield most valuable data regarding the advisability of withholding certain albuminous foods. One cannot study works upon this subject without being impressed with the intimate relationship existing between an excess of uric acid and certain neuralgic manifestations. Indeed, it is hardly possible to determine how far gout, rheumatism, and calculous diseases in general are dependent upon this same condition of uricacidemia.

That diet is a potent factor in the successful treatment of all these processes is universally accepted. Therefore it is in order to consider what foods will give us sufficient of the various elements necessary for nutrition, and at the same time leave no excess of uric acid in the circulating blood.

The gradual withdrawal of all forms of meat from the dietary, with a proportionate increase of milk, cheese, and gluten foods to supply the nitrogenous food required, and a corresponding increase in the starches, nuts, and fruits is recommended.

It is not to be inferred that the dietary is to be limited to the articles suggested in these tables. Indeed, it is surprising to note what a variety of meals can be prepared without meat and the forbidden foods. On the other hand, certain patients find it entirely impracticable to live upon this or a strictly vegetable dietary. In these instances the liberal administration of beef in the form of nutritive beef-tea and scraped or chopped meat cakes, in conjunction with a decided increase in the fats, will give the best results. The fats suitable are obtained in cream, butter, bacon, and in the yolks of eggs, in the form least likely to tax digestion and excite repugnance.

When all the exciting causes of the disease under consideration are eliminated, the diet which maintains a condition of nutritional equilibrium will be the one best suited to the case.

Neurasthenia requires an excess of easily assimilable, highly nutritious food, administered at frequent intervals, in the largest possible quantities. This particularly applies to those cases undergoing what is usually designated "the rest cure." Here the food is urged upon the patient regardless of his desires, and even despite a positive disinclination for food. Milk, cream, and other forms of fat and oils, gruels and easily digested starches, are administered at frequent stated intervals, and the patient is aided in utilizing a part of this nutriment by the administration of massage and electricity, while he stores the remainder in the form of fat and muscular tissue. Indeed, the entire plan of the treatment aims to secure a marked increase in body weight. This is in accord with the view expressed by S. Weir Mitchell, who states that "loss of fat is constantly associated with impoverished blood, and that to gain in fat is nearly always to gain in blood." Many cases of neurasthenia which do not undergo the rest cure are greatly benefited by an ocean voyage, where there is usually a condition of limited expenditure of mental and muscular effort, coupled with an inclination to ingest and ability to digest excessive quantities of food. A neurasthenic who travels for his health should not be allowed to consume, in long journeys, irregular meals, and hasty sightseeing, all the energy developed from his ability to take increased quantities of food.

Insomnia is frequently referable to one or two classes of causes:

(*a*) Improper eating or drinking before retiring.

(*b*) Deficient nutrition.

The patients of the first class require only to have the food, drug, or drink that has been causing the insomnia to be cut off, and to have the evening meal composed of easily digested food. This, with the temporary use of a hypnotic, should accomplish a cure.

In the second class of cases an effort should be made to place the patient upon a higher nutritive level by the administration of light nourishing food between meals, and a cup of hot milk, a milk punch, or malt beverage with a biscuit before retiring. A complete food, such as "Bartholow's food," taken before retiring, will frequently insure a night's repose. It is desirable to have some milk or crackers at the bedside, in case they should be required during the night. The objection to liquors and malt beverages, as an aid in inducing sleep, does not apply to this class of cases as it does to the cases of insomnia occurring in youth.

Epilepsy is so rare in the herbivora, and so frequent in the carnivora that the immunity of the vegetarian animals would seem to give us a positive dietetic indication for the treatment of this disease. Meats, particularly the coarser forms, such as bologna, seem to be especially prone to excite convulsive attacks. Gorging with food, especially improperly masticated meats and other forms of nourishment—notably peanuts—is regarded as being likely to excite epileptic paroxysms.

The intimate relationship between the ingestion of an excess of unsuitable and improperly masticated food and an epileptic seizure must be familiar to all those who have given considerable attention to this class of cases. The dietetic treatment of epilepsy promises most when the patient is under the complete control of an attendant. For this reason the epileptic colonies should secure the best results, other things being equal.

The diet that promises most for these cases is one in which meat is reduced to the lowest quantity consistent with the demand for work and growth. In early youth and old age, fish and white meat, with the occasional administration of red meat for the noon meal, are best. Aside from this, the diet should consist of cereals and vegetables, and the meals should be eaten at fixed hours. The frequency of the attacks during the night would suggest the desirability of having the evening meal composed of easily digested food.

Exanthematous Diseases.—The diseases characterized by a skin eruption in the course of an acute febrile process will demand especial dietetic direction only in those instances in which nephritis has occurred as a complication. Here milk is to be made the exclusive nourishment, until the absence of albumin from the urine indicates the improved condition of the kidneys and permits a more extended dietary.

Skin Diseases.—These, when not of parasitic origin, are frequently influenced by diet. The causal relationship between the occurrence of urticaria and the eating of certain fish, molluscs, fruits, or cereals is fully established. Certain cases of eczema, acne, psoriasis, furunculosis, dermatitis, and pruritus can be favorably influenced by attention to the character and quantity of the food. The recent work of Schamberg upon the etiology of psoriasis seems to give convincing evidence of the causal relationship between the ingestion of meat and the occurrence of this disease. That there is found associated with indigestion and lithemic states a condition favoring the development of skin eruptions, there can hardly

be any reasonable doubt. The diet outlined for lithemia will be found suitable for these cases (*vide* section on Gout). B. Franklin Stahl.

Foot.—It is natural to compare the foot, as the distal member of the lower extremity, with the hand, the corresponding member of the upper; and by such a comparison we get most valuable aid to a comprehension of its structure. It has been said that the foot is merely a hand altered by the functions of support and locomotion which it has had to perform. While it is in general true that foot and hand are constructed upon a similar plan, it must be remembered that the differentiation commences far down in the animal series. The similarity between the anterior and posterior extremities of a quadruped, such as the horse for instance, disappears to a considerable extent when the anatomical structure is closely examined. Even in quadrupedal locomotion the posterior extremities are the ones most active in propelling the body, the anterior limbs being mainly for support and equipoise. The impression of the forefeet of an unshod horse is different from that of the hindfeet on this account. As the forelimbs come to be more used for the purposes of prehension and dexterity, the difference in structure becomes more marked. The higher apes were improperly called quadrumana, for no animal, speaking strictly, has four feet anatomically similar; still less has any animal four organs that can properly be called hands. The differences are various, according to the adaptation of the anterior and posterior members for the special activities of the animal. The bones of the carpus are never found to be the same as those of the tarsus, varying either in number or in the union of the various osseous elements. There is not, properly speaking, any opposability of the great toe in apes, as it cannot be

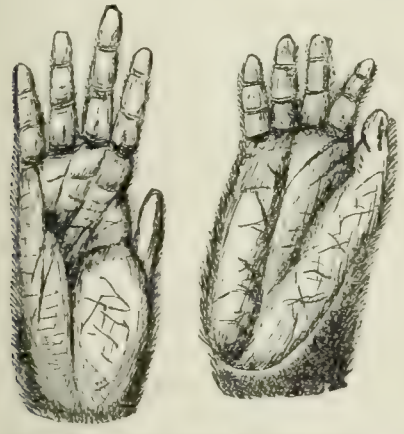


Fig. 2399.—Hand and Foot of a Chimpanzee. (Vogt.)

carried around and placed at will against the various other toes; but it is set at a wider angle than the others, so that it can be used like the curve of a pincers or of a cramp-iron for grasping and climbing. The posterior extremities of apes are merely feet adapted for walking upon trees, the resemblances of the foot or "hind-hand" to a true hand being only skin deep (Huxley[1]).

There seems from the structure of the human foot no reason to doubt that it has been developed from an organ adapted for the same use. Strong evidence of this is found in the fetal condition of the foot, which approaches in many respects that of the anthropoid apes, there being less development of the heel, an arrangement of the joints which permits more inversion of the sole, and a difference in the corresponding length of the first and second metatarsal bones, indicating that the adult condition, in which the great toe is as long as, or longer than, the others, has been gradually acquired. Lebouc[2] determined the average proportion of the first metatarsal to the second to be in the child before birth as 1 is to 1.37; at fourteen years, as 1 is to 1.21; and in the adult as 1 is to 1.17.

Fig. 2399 shows the hand and the foot of the chimpanzee contrasted, while Fig. 2400 shows the same members in adult man. In the gorilla the resemblance to the human hand and foot is still greater.

Fig. 2400.—Hand and Foot of Man. (Vogt.)

The feet of a child that has never walked show decided differences in power of using the toes, there being considerable grasp and the same imperfect opposability of the great toe as is seen in apes. The markings upon the sole show this to some extent.

The markings on the foot of a child that has never worn a shoe, nor stood alone upon its feet, resemble somewhat those of the palm of the hand, indicating considerable freedom of flexion and a certain amount of independent use of the great toe. They almost entirely disappear after the foot is used as a support. The power of the great toe may, however, be kept up if the feet are not confined, and many savage tribes use

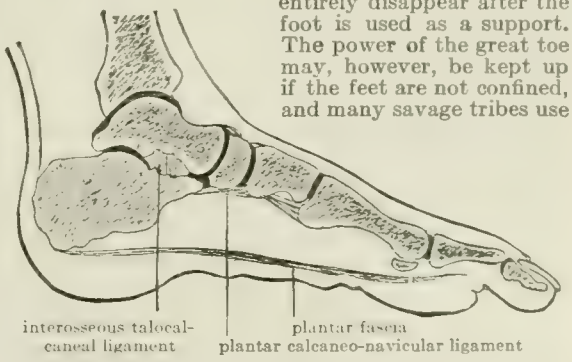


Fig. 2401.—The Anteroposterior Arch of the Foot. The bones shown are those cut by a longitudinal section through the axis of the great toe. The calcaneus forms the posterior branch of the arch; the navicular, first cuneiform, first metatarsal, the anterior branch; and the talus is at the summit. A sesamoid bone is seen under the head of the first metatarsal. In front are the phalanges of the great toe.

the foot for grasping. Among Australian savages this grasping power is of great assistance in climbing trees, and they habitually pick up a spear or similar object with the foot. Nubian horsemen are said to use the reins, and Chinese boatmen to pull an oar, by means of the great toe. Occasionally persons may be found who, either born without hands or losing them early in life, have acquired the habit of using the foot for various acts ordinarily performed by the hands, and can thread a needle (as do the Hindoo tailors), use scissors, or even write, with the toes. The fact that

walking in the erect position is learned only with difficulty shows that it is a late acquirement.

The main characteristics of the human foot are, therefore, those which adapt it for support and locomotion. For this purpose a most beautiful structural arrangement has been effected, combining great strength with peculiar elasticity and lightness. The bones are set in the form of a vault supported at the points connected by arches, two of these starting from the same point of the heel (the tuberosity of the calcaneus), and extending forward, one to the ball of the great toe (head of first metatarsal), the other to a corresponding point on the little toe. The third arch is transverse, connecting the anterior ends of the longitudinal ones.

The inner arch is formed by the calcaneus behind the first, second, and third metatarsals, the cuneiform,

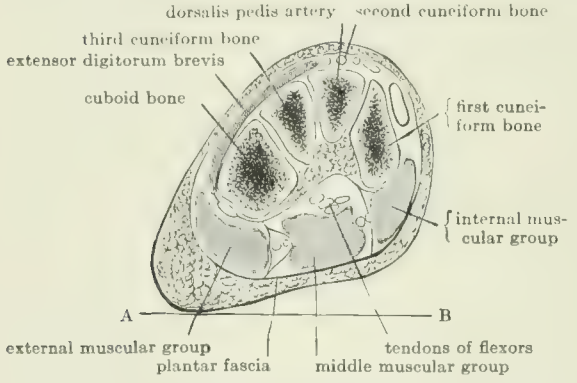


Fig. 2402.—The Transverse Arch of the Foot. Section through the anterior row of tarsal bones. The line *A B* represents the surface upon which the foot rests when the individual stands erect.

and navicular bones in front, with the talus set at the vertex as a keystone (see Fig. 2401). The outer arch, which is much flatter, is formed by the calcaneus, cuboid, and two outer metatarsals which articulate with it. The transverse arch is formed behind by the three cuneiform bones and the cuboid (Fig. 2402), in front by the metatarsal bones. It should be noted that this arch becomes shallower and shallower as the toes are approached, until at last upon reaching the heads of the metatarsals the weight is borne fully upon them all. The imprint of a normal human foot, shows this clearly. The height of the arches forms the instep, a feature peculiar to man, and which varies considerably in different races, being generally higher in the Indo-European than in others. Arabs are said to boast that their insteps are so high that water will run under them without wetting the sole, and the Andalusian instep is famous. A popular saying has it that the foot of the negro is so flat that it makes a hole in the ground. A very amusing proof of this primitive condition of the negro foot may be noticed in Southern cities, where, during the heat of summer, it is customary to wet the pavements in the evening. It is not unusual to see barefooted negro boys, whose feet are so flat that atmospheric pressure makes them adhere slightly when applied to the wet and smooth pavement, in the same way that a boy's leather sucker adheres to a smooth stone, and it is a favorite pastime with such gifted individuals to walk the streets, producing a somewhat startling report every time the foot is withdrawn from the pavement. It is perhaps not without some reason that the height of the instep is considered a mark of pure blood, as it appears to be one of the signs of complete adaptation to the erect posture and to locomotion in that position.

Man is the only animal that has the foot placed at right angles to the axis of the body, most mammalia not touching the ground with the calcaneus at all. The horse, for instance, literally walks upon the points of the toes, the hoof being comparable with the nails of the human foot, and the hock or "knee" being the tuberosity of the calcaneus. There appears to be some relation between this ascension of the calcaneus and the fleetness of the animal, as those which are the swiftest have the bones so arranged that they walk merely upon the tips. If support alone were needed there would be no necessity for the metatarsal bones and toes, as may be seen in those who have had them amputated. The anterior part of the arch is therefore for purposes of locomotion, and it may be noted that in running the heel is raised off the ground, and the anterior part only is used, the anatomical relation of the bones to the soil being similar to that which occurs ordinarily in the foot of the carnivora. The great swiftness and lightness of motion of a *première danseuse* is owing to her ability to dispense entirely with the posterior portion of the arch.

Owing to this difference of formation the anterior and posterior pillars of the longitudinal arches differ—the posterior, being for support, is short, thick, and strong, being of but one bone; the anterior, composed of several bones, is longer, so that the motion of raising the heel can be quickly performed. The length of the heel in the African race is merely apparent, and caused by the flattening of the arch rather than by a real projection. The number of bones in the anterior arch greatly aids in the distribution of the force, as any one may see who will take the trouble to note the difference in shock which occurs when alighting upon the heels rather than upon the balls of the toes.

This system is sustained by ligaments, tendons, and fascial bands in such a way as to form a most elastic and adjustable support. The longitudinal arches are held up by a strong sheet of connective tissue, one of the thickest aponeurotic structures in the body, the plantar fascia (Figs. 2401 and 2403), which is attached behind to the calcaneus, and in front divides into five slips, one for each toe, which pass forward and are mainly united to a band of transverse fibers which runs across the foot just behind the clefts of the toes.

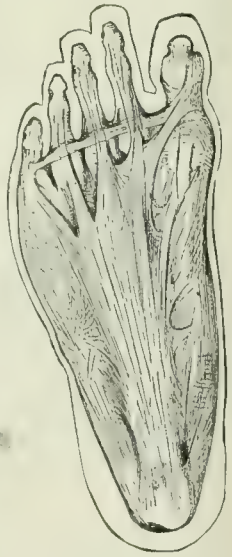


Fig. 2403.—Dissection of the Foot showing the Plantar Fascia. (Marshall.)

This braces up the arches of the foot in the same way that a tension rod prevents the rafters of a roof from spreading. This arrangement is found only in the human foot, other animals having a plantar fascia movable like that of the hand, and usually with a special tensor like the palmaris longus of the arm. The little plantaris muscle of the human leg, which does not reach the foot, but unites with the tendo-calcaneus at the ankle, is the relic of such a structure.

When this fascia is very tense, it may draw the arch so closely together as to prevent the outside of the foot from touching the ground. This condition is not usually found in the normal foot, being the result of contracture of the fascia.

Besides this arrangement, the longitudinal arches are braced at the top by strong ligaments. A glance at Figs. 2401 and 2404 will show how necessary these are. The astragalus at its inner side overlaps the calcaneus, and would, in case of a lateral thrust, be shoved downward and inward into the space between

that bone and the scaphoid were it not for the plantar calcaneo-navicular ligament, which passes from the projecting shelf of the calcaneus known as the sustentaculum tali, forward, under the talus, to the navicular. Its upper surface is lined with synovial membrane, and the cavity of the joint between the anterior part of the talus and the calcaneus is continued forward over it to the talonavicular articulation. The tendon of the tibialis posterior passes forward under this ligament, and its fibers are united with it, strengthening it materially, and by its pull upon the navicular assisting the firmness of the joint exactly at that period of the step when the arch is most in danger; that is to say, when the heel is being raised and the weight thrown forward upon the navicular. If this ligament becomes weak

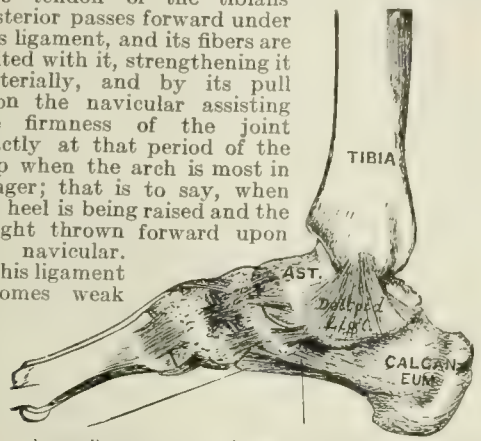


Fig. 2404.—The Ligaments on the Inner Side of the Right Foot.

or the muscle atrophied, the arch is depressed, the head of the talus descends below its proper level, and flat foot, or valgus, results. This is usually associated with arthritis, and is a very painful affection, differing much from the congenital form of the defect. It is found especially among those who stand for long periods of time.

On the outer side of the foot the arch is trussed up by means of a strong band called the long plantar ligament (Fig. 2404), passing from the tuberosity of the calcaneus forward to the base of the second, third, and fourth metatarsals.

To produce the transverse vaulting, certain short and oblique ligamentous bands are used, radiating from the navicular, the cuboid, and the third cuneiform bones, and these are assisted in a marked degree by the action of the muscles.

Fig. 2405 shows that the tendons of the peroneus longus and of the flexor digitorum longus are so arranged that they pull obliquely upon the bones of the foot, crowding them together and consolidating them transversely. Duchenne[3] was of the opinion that flat foot is frequently associated with an insufficiency in the peroneus longus. The members of the inner arch are decidedly more movable than those of the outer, which recalls the fact that it is only the outer part that is used for support among anthropoids.

The various interosseous ligaments assist considerably to keep the bones in place. The strongest of them is the one between the talus and the calcaneus (Fig. 2401), separating the articular surface into two distinct portions. It lies within a canal formed by grooves upon either bone, and known as the sinus tarsi, surrounded in that situation with fat.

The joints of the foot are adapted to the arch-like form above described. An inspection of Fig. 2401 will show that there is an approximation in these joints to arcs of circles, the larger arcs being in the posterior part of the arch, the smaller and more numerous forward. A study of the cancellated tissue of the bones shows that these arcs are continued to some extent by strengthening bars within the bone, showing that conditions of stress have occasioned this arrangement. The movements are generally those of rotation and not purely gliding (Bradley[4]). A uniformity of distribution of pressure is thus obtained. The ligaments which unite the different bones are of two classes: those which are special, surrounding and supporting particular joints; and those which are general, mainly employed in bracing and sustaining the arches of the foot. To the first class belong the capsular ligaments which are found at every joint, and are strengthened more or less by special bands, which receive names from the bones which they unite. The principal ligaments of the second class have already been mentioned. The movements are of two classes, one of which is a simple flexion and extension, mainly expressed in the joint between the talus and the leg bones (see *Ankle Joint*), and in the various metatarsal and phalangeal joints; the second a movement of inversion and eversion of the sole, sometimes called, rather inaccurately, adduction and abduction, or supination and pronation, and which takes place in the joints. As already mentioned, the joint between the talus and the calcaneus is double, with two synovial sacs, the anterior being continuous with the talonavicular articulation. The joint has been carefully studied by Miss Clark,[5] who made many measurements of it, both in fetal and adult subjects. The facets on the talus are concave, and the axis of motion is a line extending from the insertion of the dorsal ligament binding the talus to the navicular through the head of the talus and the body of the calcaneus obliquely downward and backward to about the point where the calcaneofibular ligament is inserted. The movements which take place are really a nearly simple flexion and extension about this oblique axis, the former turning the sole inward (supination), the latter slightly outward (pronation). The arrangement of the axis of motion with reference to the axis of the talus is different in the fetus, resembling that of anthropoids. The whole bone is quite differently shaped as regards the inclination of its articular surfaces, they being adapted to the fetal position, which is that of dorsal flexion and inversion of the foot. The head of the talus is so directed as to make the axis of the bone more nearly coincide with that of the motion of the joint. Inversion is therefore easier and more complete. The shape of the articular facet on the head of the talus is also different, its greatest diameter being less oblique than in adults. In the ape's foot inversion of the sole is necessary for climbing, and among Australian savages it is similarly used. This movement is undoubtedly very useful in correcting slight disturbances of equilibrium when standing erect. The direction of the facets in the adult is such that when the posterior part of the calcaneus slips forward and downward the anterior facet moves backward and upward, carrying the distal end of the bone slightly inward. For this reason inversion is always accompanied by a turning in of

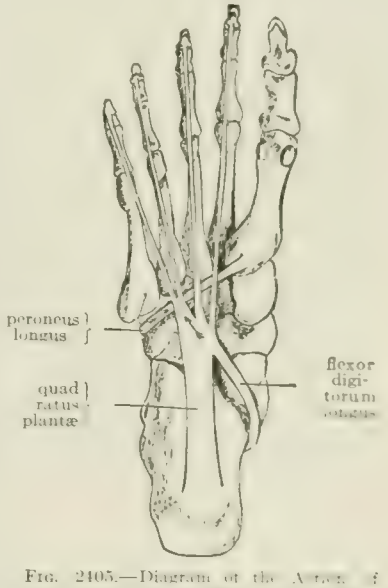


Fig. 2405.—Diagram of the Arches of the Foot. Some of the Principal Tendons which Consolidate the Transverse Arch of the Foot.

the toes, and eversion by turning them out. A further degree of this movement of the toes is found in the talonavicular, a shallow ball-and-socket joint, the round head of the talus being received into the posterior hollow facet on the navicular. It is this joint that gives to the foot the great freedom of movement that is enjoyed by dancers. A comparison of these joints with those of the wrist will show at once that there is no real homology possible between them. Dislocation may occur here, the interosseous ligament being torn and the malleoli usually fractured at the same time.

The peculiar condition of the fetal foot, with reference to this joint, is probably the primary cause of the different varieties of club foot. The most common form, or varus, is the persistence of the fetal condition of inversion of the sole. The articular surfaces between the calcaneus and the cuboid are saddle-shaped, and have a triangular outline. The movements allowed here are like those of the talonavicular joint, but less in extent. The whole articular line between the talus and calcaneus behind, and the navicular and cuboid in front, is known as the mediotarsal joint, sometimes called Chopart's joint by surgeons because of the operation frequently performed there. The movements of the other joints of the foot are similar to the corresponding ones of the hand. The great toe is the only one that lies perfectly extended, the others being more or less flexed. Together they give elasticity to the last act of walking, when the weight is thrown forward upon the other foot.

In considering the surgical anatomy of the articulations of the foot, it is necessary to note that the bones fall naturally into three grand divisions of tarsus, metatarsus, and phalanges, and that the tarsal bones are divisible into an anterior group, composed of the three cuneiform bones, the cuboid, and the navicular, and a posterior group, the calcaneus and the talus. The talus may itself be considered separately, as it lies more superiorly and with a horizontally directed joint surface. There are, therefore, the following lines in which disarticulation can be effected: First, between the different phalangeal and metatarsophalangeal joints; second, the tarsometatarsal line; third, the mediotarsal line; fourth, the subtalic line; and, lastly, the crurotarsal line, by which the entire foot may be removed. The phalangeal joints are easily found by remembering that it is always the proximal phalanx that forms the prominence in flexion, and

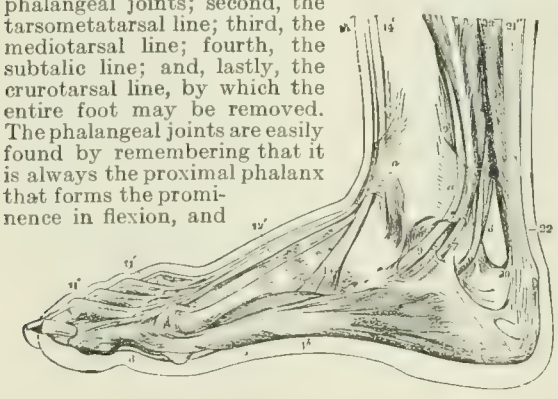


Fig. 2406.—View of the Muscles and Tendons on the Inner Side of the Right Foot. *a*, *i*, Transverse crural and laciniate ligaments; 1*b*, abductor hallucis; 7′, tendon of flexor digitorum longus; 8′, tendon of flexor hallucis longus; 9′, tendon of tibialis posterior; 11′, tendons of extensor digitorum longus; 12′, tendon of extensor hallucis longus; 14′, tendon of tibialis anterior; 22, tendo calcaneus. (Marshall.)

that the opening must therefore be somewhat forward from that. The same may be said for the metacarpophalangeal joints, the general line of which lies about three-fourths of an inch behind the skin fold connecting the toes. The exposed condition of this part of the foot, as well as its distance from the heart, renders it liable to some injuries, such as chilblains, and senile gangrene. The tarsometatarsal line is used for the operations of Hey and Lisfranc, neither of which is frequently performed, as disease is very rarely confined to the metatarsal bones. Hyrtl's[7] rule for finding the joint on the inner side is that it lies exactly at the half-length of the sole. It is also about an inch and a half in front of the tuberosity of the navicular, which may be easily felt on

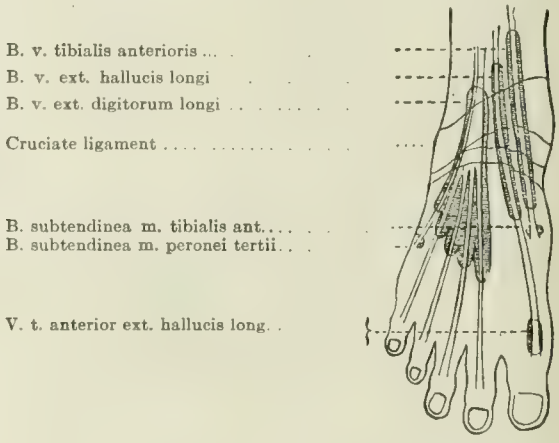

B. v. tibialis anterioris
B. v. ext. hallucis longi
B. v. ext. digitorum longi
Cruciate ligament
B. subtendinea m. tibialis ant.
B. subtendinea m. peronei tertii
V. t. anterior ext. hallucis long.

Fig. 2407.—Synovial Sheaths on Back of Ankle and Foot.

the inner side of the foot in front of the point of the internal malleolus. A slight eminence may usually be felt on the posterior extremity of the first metatarsal by holding the foot steady, pressing firmly on the skin, and thus following back the smooth internal surface of the shaft of the bone. On the outer side the line cannot be missed, as it lies directly behind the prominent tuberosity at the base of the fifth metatarsal. The base of the second metatarsal bone is received between the first and third cuneiform bones, the second cuneiform being correspondingly lessened in length. This adds considerable firmness to the arches, but makes the line quite irregular and is an obstacle to the speedy performance of the operation. Disarticulation is now usually practised; but Hey sawed through the metatarsal, leaving the base in place. Tillaux[8] remarks that although the irregularity of the line varies, the joint of the second cuneiform is always at a definite interval behind that of the first—about a centimeter. The interosseous ligaments are strong, and are the principal obstacle to the knife.

In the mediotarsal line the operation known as Chopart's is performed. The line is not very difficult to find as it lies on the inner side just behind the tuberosity of the navicular, and externally just in front of the prominent edge of the head of the calcaneus. This latter is midway between the fibular malleolus and the tuberosity on the metatarsal bone of the little toe. There is no irregularity in the line, it being composed of two curves, one between the navicular and talus, convex forward, the other between the calcaneus and cuboid, convex backward. The principal obstacle to the knife is the bifurcated or Y-ligament, which is strong and thick, radiating, as mentioned before, from the calcaneus to be inserted by two slips into the cuboid and the navicular. The calcaneo-navicular ligament which, it will be remembered, ties the vertex of the arch, is also divided in this operation. In old subjects it is occasionally found to be ossified.

Disarticulation under the talus is not often resorted to. As there are no muscles attached to that bone, it can be of little service even if left in place.

The muscles of the foot are divided by their position into intrinsic and extrinsic; those which have their

origin above belonging to the latter class. The division is topographical rather than scientific, for there is no doubt that many of the muscles now found in the foot primarily had an origin higher up, and have become displaced in the course of phylogenetic development.[9] The extrinsic muscles are the most active agents, the intrinsic mostly aiding and supplementing them. They fall quite naturally into four groups—an anterior, supplied by the deep peroneal nerve and composed of the tibialis anterior, extensor hallucis longus, extensor digitorum longus, and peroneus tertius; a lateral, supplied by the superficial peroneal nerve and composed of the peroneus longus and brevis; and two posterior, the superficial supplied by the tibial nerve and composed superficially of the muscles inserted into the tendocalcaneus (gastrocnemius, soleus, plantaris), and deeply of the tibialis posterior, flexor digitorum longus, and flexor hallucis longus. All of these pass over two joints, the ankle-joint or talocrural and the talocalcaneal, and therefore occasion motion at both, but in very varying degrees.

The tendons of the anterior group may be seen in Figs. 2406, 2407, and 2413, and passing down over the ankle, where they are held in position by thickened bands of fascia known as the annular ligaments. There are three of these, an upper one the transverse crural ligament extending across the lower part of the leg from fibula to tibia, an anterior one, the cruciate crural ligament in the form of a ≺, placed thus on its side (the shape best shown in Fig. 2407) and an internal one, the laciniate ligament. The main stem of the cruciate ligament is a strong loop-like band which lies on the outer portion of the ankle, springing from the fore part of the calcaneus in the deep fossa between that bone and the talus known as the sinus tarsi. It completely surrounds the tendons of the peroneus tertius and extensor digitorum longus (see Fig. 2408, *a*). This band was first described by Retzius, who gave it the name of ligamentum fundiforme tarsi. It is of considerable strength, and gives a new direction to the tendons, so that they pull more exactly in the line of the toes (see Fig. 2413), thus forming a sort of trochlea like that which the superior oblique muscle of the eye has. According to Hyrtl it usually becomes cartilaginous in old people. By a sprain the tendons may be torn from this connection, and will then be seen to take a much more direct line to the toes. From this band the two branches of the cruciate ligament diverge, passing over the tendons of the extensor hallucis longus and the tibialis anterior. The tendons which pass down over the dorsum are provided with certain synovial sheaths which are shown in Fig. 2407. The tendon of the tibialis anterior (14′ in Fig. 2406) is the largest and strongest, and may be easily made out whenever the foot is flexed and the sole at the same time bent inward. As it is inserted into the first cuneiform and base of the first metatarsal, it necessarily flexes the foot and inverts the sole. It will be seen that the attitude is much like that of varus, and in fact this muscle is one of the most active agents in that deformity. In dividing the tendon care must be taken not to open the talocalcaneal joint.

The tendon of the extensor hallucis longus comes next (see Fig. 2413). It is also very large and strong and is the most prominent cord in front during flexion of the foot. On this account it is the first to suffer from any tightness of the covering about the ankle. It is inserted into the last phalanx of the great toe, which it strongly extends in the last act of walking just as the foot is about to leave the ground. Continuing its action, it flexes the foot on the leg and assists the tibialis anterior to invert the sole. It is more firmly enclosed by the cruciate ligament than the tibialis anterior, and its pull upon that band raises the arch slightly so that its impression is fainter.

The extensor digitorum longus sends tendons to the four outer toes which unite with those of the extensor brevis and are inserted into the second and third phalanges. Closely associated with this muscle is the peroneus tertius, a thin muscular slip which sends a tendon to the metatarsal bone of the little toe. It hardly deserves a separate name.

The action of the extensors upon the toes is reinforced by the lumbricales from the sole of the foot. These muscles arise from the *flexor* tendons and pass around the phalanges to be inserted into a triangular aponeurosis, which is common to the extensor muscles. In walking, therefore, as the flexors assist in raising the foot they give a firm basis for the pull of the lumbricales, so that in the final act of rolling the weight forward upon the toes they can assist the extensors. It should be remembered that the division of the muscles into flexors and extensors is not, in so far as it implies an antagonistic condition, entirely correct.[10] Those muscles which extend the toes also flex the foot, and *vice versa*. There is no loss of muscular force, as there would be did one set pull directly against the other.

The extensor brevis (see 10, Fig. 2408), though an intrinsic muscle, should be mentioned here, as it belongs morphologically to the same group. It was originally a leg muscle, and has gradually slipped down, all stages of its descent being seen in different animals.[9] It arises from the forepart of the upper and outer surfaces of the calcaneus, and presents, on the outer side of the foot, a considerable muscular belly, which contributes to the modelling of that part of the foot, and is soft and pulpy to the touch. This should be remembered in examining the ankle for suspected joint disease, or after a sprain. When struck lightly it will quiver, and this movement has been mistaken for fluctuation, and the muscle has been incised in mistake for an abscess. The tendon which goes to the great toe is usually somewhat separated from the others, and that part of the muscle has been described separately as an extensor hallucis brevis.

The extensor brevis varies considerably, especially with regard to the amount of division of the various muscular bellies of which it is composed, and there is occasionally seen a tendency for it to become merged with the dorsal interossei, elements of an entirely different origin.

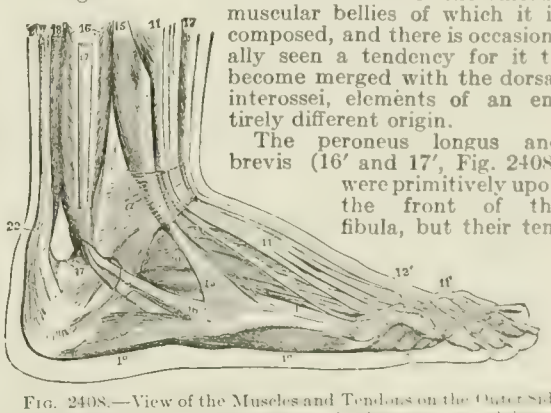


Fig. 2408.—View of the Muscles and Tendons on the Outer Side of the Right Foot. *a*, Ligamentum fundiforme; 14, abductor minimi digiti; 7′, insertion of the tendons of the flexor digitorum longus; 10, extensor digitorum brevis; 11′, tendons of the extensor digitorum longus; 12′, tendon of the extensor hallucis longus; 15, tendon of the peroneus tertius; 16′, tendon of the peroneus brevis; 17′, tendon of the peroneus longus; 22, tendo calcaneus. (Marshall.)

The peroneus longus and brevis (16′ and 17′, Fig. 2408) were primitively upon the front of the fibula, but their tendons have been shifted behind the outer malleolus for adaptation to climbing. They are here held by a strong sheet of fascia (retinaculum superius), and are similarly sheathed (retinaculum inferius) where they lie in a groove on the outer side of the calcaneum. Notwithstanding this secure attachment the tendons are more frequently displaced than any others in the body. Leaving the groove they diverge from each other, the brevis being inserted into the tubercle of the fifth metatarsal, and continued by a thin tendon as far as the toe, the longus passing across under the arch of the foot in the groove on the inferior

surface of the cuboid, and being inserted into the tubercle of the first metatarsal bone (see Fig. 2405). They strongly evert the sole, producing a condition like that of valgus.

The peroneus tertius, the extensor digitorum, longus and the extensor digitorum brevis, were originally parts of the same muscle sheet which belonged to the back of the foot and front of the leg. The twisting over of the foot into its position with the plantar surface downward has caused them to appear in their present situation. Extra peroneal muscles are not infrequent, and in one dissection performed by the author a set of five were found.

The main body of the flexor tendons passes down on the inner side of the ankle. Fig. 2409 shows, in a diagrammatic form, how they are arranged, and their tendons are seen in Fig. 2406. Besides these there should be mentioned those muscles (the soleus and gastrocnemius) which are inserted through the tendo calcaneus upon the calcaneus. Duchenne's experiments[3] in the faradization of muscles led him to the conclusion that these latter act as extensors and adductors of the foot, while the peroneus longus is an extensor and abductor. In order to get a powerful and equal extension of the foot these act together, and this may be increased by a simultaneous contraction of the flexor digitorum longus and flexor pollicis longus. He supposes that the reason for the peculiar action of the tendo calcaneus in causing adduction is occasioned by the arrangement of the plantar ligaments. The strongest bands lie on the lateral side of the foot, and this determines a deviation of the line of action in that direction.

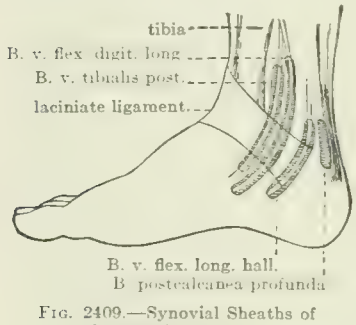


Fig. 2409.—Synovial Sheaths of Inner Side of Foot.

It was formerly supposed that the severing of the tendo calcaneus was necessarily a fatal injury. Hippocrates was firmly of this opinion, and one of the names given to the tendon is chorda magna Hippocratis. It was undoubtedly a serious matter when the wound was an open one and proper drainage not secured; but with the modern resources of surgery it is often safely divided for the relief of club foot. For about an inch and a half above its lower end it is free from muscle fibers, and narrows slightly, and it may be cut there, care being taken to avoid the vessels and nerves at its inner side, and the bursa which exists just above its insertion (see Fig. 2409). Rupture of the tendon has occurred from violent muscular action in jumping.

The tendons of the tibialis posterior, the flexor digitorum longus, and the flexor hallucis longus pass down behind the internal malleolus in a special compartment, confined by a strong band of fascia known as the laciniate ligament, which passes from the malleolus to the calcaneus, enclosing not only the tendons but the vessels and nerves which accompany them. They have special synovial sheaths (Fig. 2409), and are so arranged that the tendon of the flexor hallucis longus is nearest the tendo calcaneus, that of the flexor digitorum longus next, and that of the tibialis posterior nearest the malleolus, the tendon of the digital flexor twisting around it from without inward, and then passing downward, forward, and outward under the sole. Were it not for this the tendon of the tibialis posterior would be likely to slip from under the malleolus or the sustentaculum tali as it passes forward to be inserted into the tuberosity of the navicular, and by a tendinous expansion into all the bones at the upper part of the vault except the talus. It strongly inverts the sole and raises the head of the first metatarsal. Spigelius called it musculus nauticus, because it is necessarily used by sailors in climbing masts.

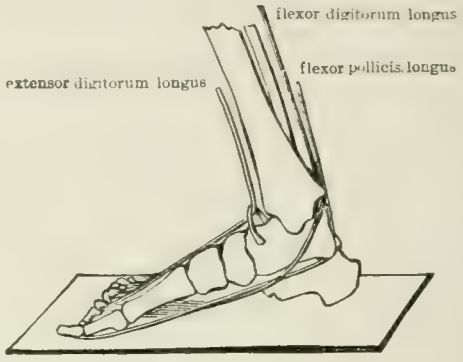


Fig. 2410.—Diagram Showing the Manner in which the Flexor and Extensor Tendons are Reflected around the Ankle. (Langer [13])

The flexor digitorum longus and the flexor hallucis longus are arranged somewhat like the flexor digitorum profundus and the flexor pollicis longus of the hand, as they have an arrangement of tendons which pass in a similar way through those of the flexor brevis to be inserted into the terminal phalanges of the toes. But they are very differently related in the sole, for they not only decussate and unite there, but the flexor digitorum longus receives a reinforcement from an accessory head, the quadratus plantæ, or caro quadrati Sylvii, arising from the tuberosity of the calcaneus, and inserted at the decussation. The crossing in the sole is such that in the greater number of cases the tendon of the flexor hallucis sends to the decussation a lateral twig, which again divides in slips for the second and third toes, uniting with the tendons of the flexor

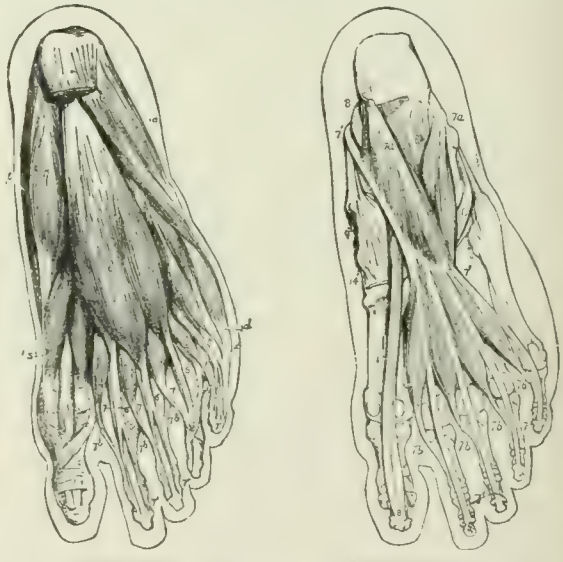
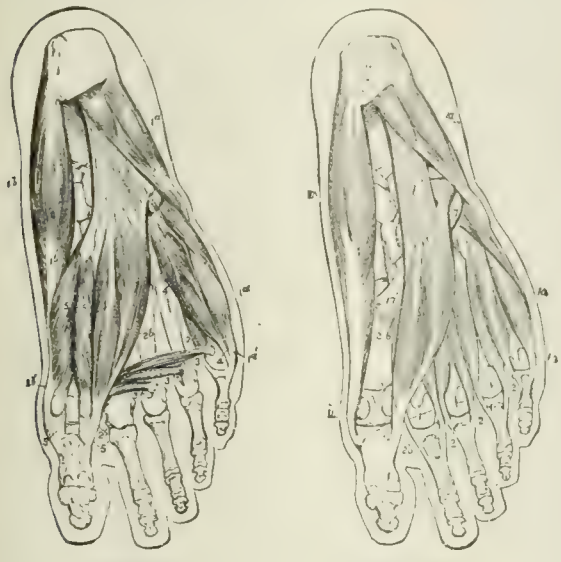


Fig. 2411.—The Muscles of the Sole of the Foot. 1*a*, Abductor minimi digiti; 1*b*, abductor hallucis; 6, flexor digitorum brevis; 7′, tendon of flexor digitorum longus; 7*a*, its plantar head, or flexor accessorius; 7*b*, 7*b*, lumbricales; 8′, tendon of flexor hallucis longus; 17, tendon of peroneus longus; 9′, insertion of tibialis posterior.

digitorum. The slip to the third toe may be wanting, but sometimes one is sent to the fourth. This arrangement recalls the musculature of the ape's foot, where the hallucis tendon supplies the third and fourth toes, and sometimes the second, while the digital tendon is mainly confined to the second and fifth, or to the



Third Layer. Fourth Layer.

Fig. 2412.—The Deep Muscles of the Sole. 4, 4, Flexor digiti quinti brevis; 5, 5, flexor hallucis brevis; 2b, adductor pollicis, with its detached heads, 3, 3, 3, also called the transversus pedis; 1, 1, 1, dorsal interossei; 2, 2, 2, plantar interossei.

second only, the great toe receiving only a slender tendon which quite fails in the orang. The unusual development of the hallucis in man appears to be connected with the use of the great toe for preserving the equilibrium in the erect position.

The plantar head mainly reinforces the tendons for the third and fourth toes.[11] The whole apparatus appears to indicate that the original plan was for a flexor fibularis (flexor hallucis longus) and a flexor tibialis (flexor digitorum), and that the quadratus originally belonged to the latter muscle, but afterward lost its insertion upon the fibula. Variations are found which tend to confirm this.

It will be noticed that the most direct pull appears to be toward the second and third toes; the tendons there are supplied, not only from the common flexor, but also from the tendon of the hallucis. This would appear to show that the original axis of the foot, or line on which it rolls, is not through the great toe, as usually stated, but through the second and third toes, and would bear out the experiments of Beely,[12] who found that in a cast taken from the impression made by his foot while standing upon a layer of soft plaster, the heads of the second and third metatarsals made a deeper impression than any other portion of the anterior part of the foot.

The action of the flexor is to bend the toes and contribute to the stability of the foot in standing. After bending the toes it also flexes the mediotarsal joint.

So it follows that these muscles all cooperate in lifting the heel from the ground and flexing the foot, and that, as this is done, the toes are strongly flexed and pressed against the ground like an elastic spring (see Fig. 2410).

They are often divided in orthopedic operations, usually at the malleolus, as it should be remembered that the posterior tibial artery lies near the flexor digitorum longus, being exactly in the middle of the space between the posterior margin of the internal malleolus and the internal border of the tendo calcaneus. The nerve is in the same sheath with the artery and behind it.

The intrinsic muscles of the sole, which are quite numerous, are shown on Figs. 2411 and 2412. They are arranged in three groups, separated from each other by appropriate layers of fascia, as shown in Fig. 2402. The external group is composed of muscles relating to the little toe, the flexor brevis and abductor minimi digiti; the inner is a similar group relating to the great toe, the flexor brevis and abductor hallucis; while the middle set is related to the muscles which come down from the calf, the quadratus plantæ and the lumbricales, together with the flexor digitorum brevis and adductor pollicis. Deep under all these lie the interossei. The muscle sometimes described as transversus pedis is now accepted by the evidence of embryology a portion of the adductor pollicis.

These muscles are of special use in supplementing the action of the ligaments in supporting the arches, giving an elastic support variable according to the nature and direction of the strain. The interossei are in two groups, the plantar and the dorsal, the lat-

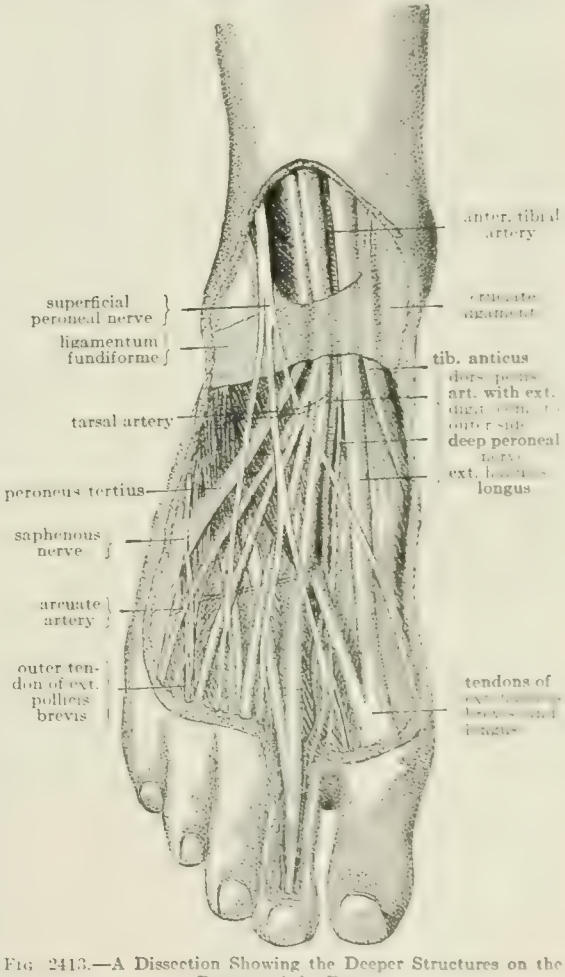


Fig. 2413.—A Dissection Showing the Deeper Structures on the Dorsum of the Foot.

ter not being prominent on the sole. All originally developed upon the sole, the dorsal having gradually passed up between the metatarsal bones during fetal life. Cunningham[14] thinks that the primitive typical arrangement of the intrinsic plantar muscles is the same as that of the hand, viz., that there is a plantar layer of adductors of the toes represented by the

adductor hallucis and its detached head, the transversus pedis, and the three plantar interossei; an intermediate layer of flexores breves, composed of the flexor brevis minimi digiti and the flexor hallucis brevis; and a dorsal layer of abductors of the toes represented by the abductor hallucis, the abductor minimi digiti, and the dorsal interossei. The layers have lost their relative planes in the foot partly because of the arched condition, and partly by suppression of the flexores breves for the second, third, and fourth toes.

The nerves of the foot give us important evidence with regard to the value and previous history of the muscles. Those derived from the lumbar plexus do not have any motor functions, but supply sensation to the integument of the inner side (saphenous nerve). The sacral plexus gives sensations to the remaining portions, viz., by the sural nerve on the inner side, the superficial peroneal over the dorsum, and the plantar nerves on the sole, the medial plantar supplying the first three toes and half of the fourth, the lateral supplying the other half of the fourth and the fifth. The nerves of the dorsum are shown in Figs. 2413 and 2415; those of the sole in Fig. 2414.

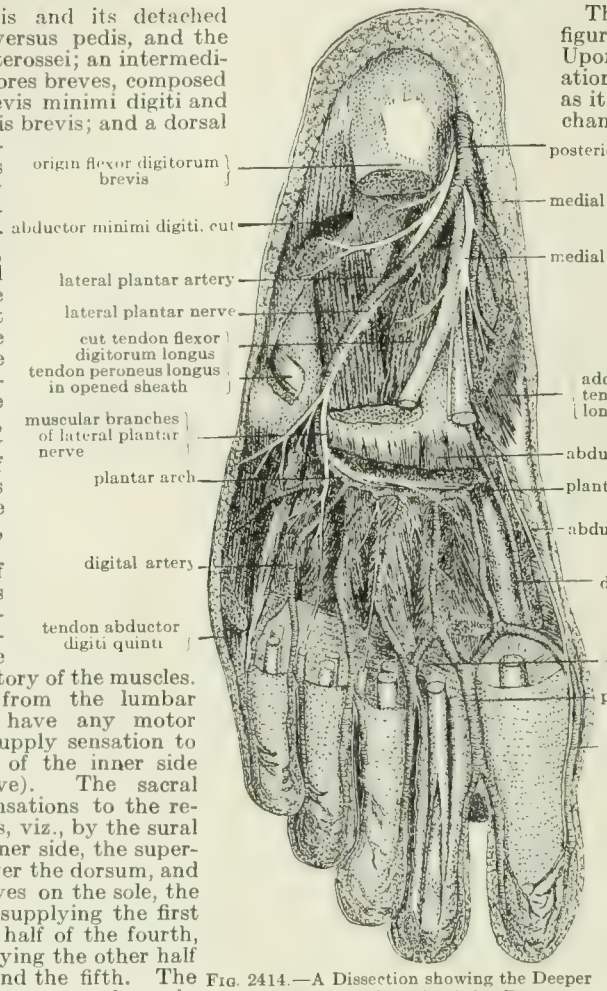


Fig. 2414.—A Dissection showing the Deeper Structures on the Sole of the Foot.

The vessels of the foot (see the same figures) are not very numerous or large. Upon the dorsum we have the continuation of the anterior tibial artery, which, as it passes under the cruciate ligament, changes its name to dorsalis pedis. It is accompanied by two veins, and passes forward to anastomose, at the space between the first and second toes, with the lateral plantar. It is believed to correspond to the radial artery of the hand, and it will be seen that the twisting over of the dorsal surface has given it a less devious course. It is easily secured in the upper part of its course, where it lies quite superficially and just external to the tendon of the extensor hallucis longus. Aneurysm has occurred in it as a sequel to a sprain. The posterior tibial artery, coming down behind the ankle, divides, just before entering the sole, into lateral and medial plantar, the latter being the smaller. The lateral runs outwardly across the foot, deep under the muscles, and then turns again to the inner border and anastomoses with the dorsalis pedis. It is not practicable to reach these for ligature in the sole, except by resection of the metatarsal bones.

The superficial veins are found mainly upon the dorsum. A reference to Fig. 2415 will show that the great and small saphenous veins arise from an anastomotic arch that extends across the metatarsal bones, with the convexity toward the toes. Tight boot-lacings may so compress these veins as to produce a stasis, with pain and swelling. Veins of any considerable size are wanting upon the sole.

The integument of the sole of the foot is intimately united with the layer of subcutaneous fat, which is here not loose and movable, but shut into distinct compartments by septa of connective tissue. This forms a very compact and elastic cushion for supporting the weight of the body.

Smallness of these members has

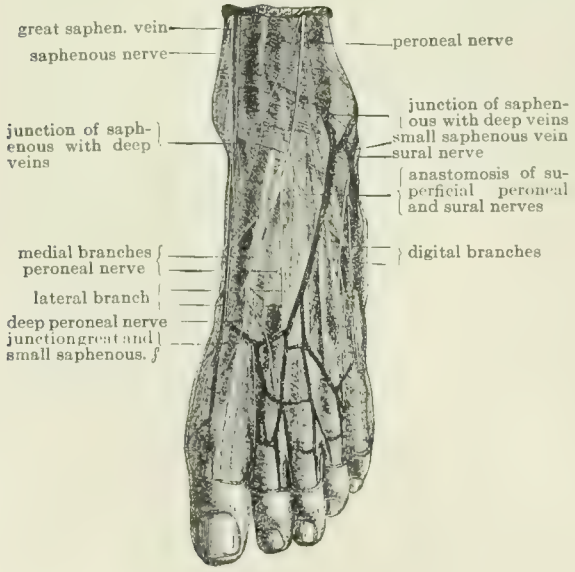


Fig. 2415.—The Superficial Veins and Nerves of the Dorsum of the Foot.

Fig. 2416.—Deformed Foot of a Chinese Lady of Rank. (Langer.)

been during all modern times considered a mark of beauty. There seems to be no good reason for this, except that it indicates a general delicacy of construction of the body and can hardly be associated with habits of labor. Structurally a small foot would seem to be an ineffective organ. The Chinese women of rank are, as is well known, so treated in infancy that the foot has no opportunity to grow, and soon becomes misshapen, as shown in Fig. 2416, reduced from a photograph by Welcker. The operation commences

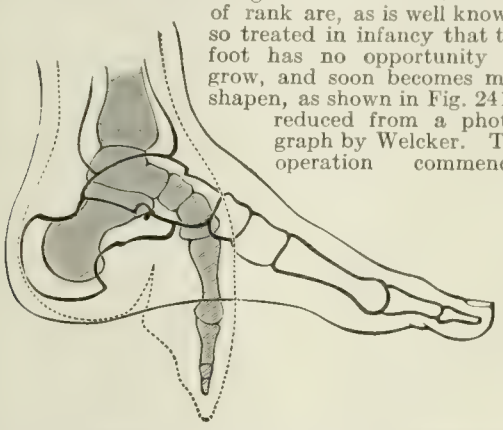


Fig. 2417.—Section of Natural Foot with the Bones, and a Corresponding Section of a Chinese Deformed Foot. The outline of the latter is dotted, and the bones are shaded. (Flower.)

usually in the second year of the child's life, and consists in turning the toes under the sole and confining them there by bandaging. The procedure is said to be quite painful, and sometimes fatal to delicate children. If the parents belong to a class in which labor will be required of the child, nothing further is done, and the foot, though deformed, can still be used for walking. If they are wealthy, the deformity is carried further by so bandaging the foot that the great toe approaches the heel as nearly as possible. As to the motive for this strange custom, it seems probable that it originated in an attempt to increase the value of the female as an object of sexual appetite. As the woman can move about but little, a greater deposit of fat is found on the mons veneris, and the nymphæ are thickened. Besides this, it is said these deformed feet are kept carefully covered, because they resemble in appearance the vulva. Only prostitutes display their feet, and for the purpose of enticing customers (Stricker[15]). Fig. 2417 shows the skeleton of such a malformation. Frank Baker.

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Foot, Disabilities of the.—I. The Weak Foot (Splay foot; flat foot). The most common and by far the most important of the disabilities of the foot is the so-called flat foot. This affection, although so common, is still imperfectly understood and in order to make its etiology, and the principles that should govern its treatment, clear, one must contrast the appearance and the functional ability of such a disabled foot with those of the normal member.

The foot is supported by ligaments, by the muscles, and by the strong plantar fascia that covers in the sole. When it is in active use it is controlled by the muscles, but when it serves as a passive support, as in standing, the ligaments bear the greater part of the strain, and its normal elasticity allows the bearing surface to expand as the arches are slightly depressed. It must not be understood, however, that the longitudinal arch is simply flattened by direct pressure and by elongation of elastic ligaments and fascia. Ligaments and fascia are not elastic and they are not, in the normal foot, overstretched. The change in contour is the effect of normal motion in the joints of the foot, by which it is placed in the most favorable attitude for weight bearing without muscular exertion.

Of the changes of contour that distinguish the foot used as a passive support from the one that bears no weight, the most significant is the obliteration of the outward curve of its internal border. This change is due to the fact that the astragalus, bearing the leg, rotates inward and downward on the os calcis until it is checked by the resistance of the ligaments and by the interlocking of the bones. The head of the astragalus thus becomes slightly prominent; the inner border of the foot is depressed, and an attitude is attained in which the weight of the body may be supported with but slight muscular exertion. This position of the foot is one of a series of similar changes in the relation of the bones of the lower extremity, which are instinctively assumed when the limb is placed in the so-called attitude of rest.

The second function of the foot is as a lever to raise and to propel the body. The calf muscles supply the

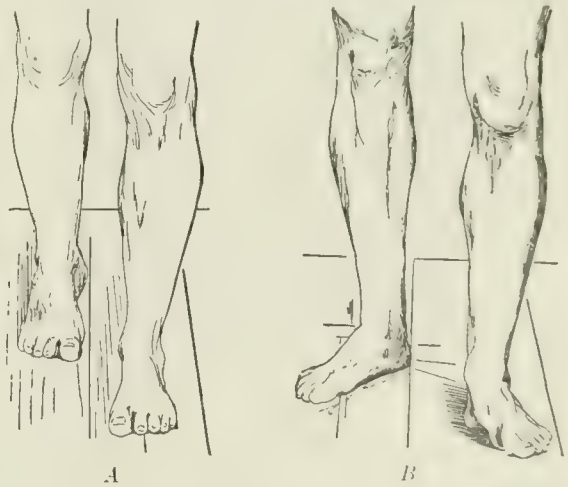


Fig. 2418.—*A*, The Proper Attitude in Activity. *B*, The improper attitude of outward rotation of the limb.

power and the heads of the metatarsal bones serve as the fulcrum on which the weight is lifted. When the foot is used as a lever it should be held in such relation to the leg that the line of weight, passing downward through the center of the knee and ankle joints, is continued over the second toe or practically the center of the foot. As the body is lifted over the fulcrum, the fore foot is turned inward in its relation to the leg or, more properly speaking, the leg is turned outward,

because the inner side of the fulcrum, formed by the first metatarsal bone, is longer than its outer side. Thus the strain is directed toward the outer and stronger side of the foot (Fig. 2418, *A*).

In the proper walk, which is the best illustration of the leverage function, the feet should be nearly parallel to one another, so that the line of strain may fall through the center of the foot. As one foot is advanced it first bears weight momentarily on the heel, then upon its outer border; the heel is then raised and the body is lifted over the toes, the great toe giving the final impulse, so that if the walker is looked at from behind, he appears to be in-toeing at the termination of each step. Thus, during the walk, there is an alternation of postures, and the foot, under muscular control, assumes the attitudes most opposed to that of passive support.

The alternation of postures and the leverage action are by no means necessary to simple progression; for example, both feet might be fixed in plaster bandages yet walking would be possible just as it is possible on two wooden legs. Indeed an approximation to such a manner of walking is often seen, in which the passive attitude persists. Such a walk is necessarily jarring and ungraceful, and if it is not the result of weakness and deformity it predisposes to them because of the disuse of the proper function of the foot.

One of the most common causes of disuse of the leverage function is the custom of turning the feet outward. This is normal in the passive attitude of weight bearing, because it locks the joints and throws the strain upon the ligaments to relieve the muscles (Fig. 2418). On this very account it is the improper attitude for activity because the strain falls upon the inner border of the foot or to the inner side of the fulcrum, making the proper exercise of muscular power, and alternation of postures, impossible.

The persistence of an improper posture may be simply a habit, but it is evident that if an individual were overweighted by a heavy burden he could not

Fig. 2419.—Typical Weak Foot of Moderate Degree, Illustrating the Component Elements of Abduction and Depression of the Arch.

walk with an elastic step, nor could he, if his muscular power were insufficient for normal activity, nor if the structure of the foot were weak, nor if active movements caused pain. In any one of these instances the passive attitude would be assumed habitually and the foot would approximate in appearance, to a greater or less degree, the so-called flat foot which is merely an abnormal persistence, and an exaggeration of, the attitude of rest (Fig. 2419).

If one contrasts the appearance of the foot in activity, under the control of, and supported by, the muscles, with one that is inactively supporting weight, he will appreciate the distinction between activity (strength) and passivity (weakness). If then the foot is habitually used in the passive attitude it may be properly called a weak foot, because it is weak in the sense that it is in danger of progressive deformity of which the sensation of weakness is the earliest and most constant symptom. Many weak feet, in the early stage at least, would not be recognized as deformed (flat) feet, and in a fair proportion the arch is well formed and even accentuated. Flat foot is therefore a misnomer, and it is an especially unfortunate term, in that it calls attention to deformity rather than to disability. The term weak foot will be used therefore to include all varieties of disability of the foot which are characterized by the habitual attitude of inactivity, of which only the advanced types might be properly described as flat feet.

Fig. 2420.—The Normal Relation of the Astragalus to the Os Calcis.

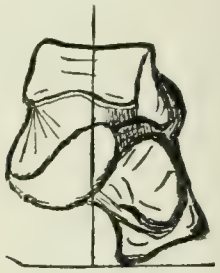


Fig. 2421.—The Relation of the Astragalus to the Os Calcis in the Confirmed Weak Foot.

The Anatomy of the Weak Foot.—As has been stated, a persistence of the attitude of rest or inactivity is characteristic of the weak foot. This attitude in which the weight falls upon its inner border is sometimes called pronation or eversion of the foot, and, when at all marked, it might be described properly as valgus. This latter term is, however, usually associated with more advanced or fixed deformity (talipes) and it is therefore rarely applied to the disability under consideration.

One may analyze the attitude and the deformity of the weak foot somewhat as follows: 1. The leg is displaced inward so that the weight falls upon the inner side of the foot. 2. The leg is rotated inward so that a line drawn through its center prolonged from the crest of the tibia, instead of falling over the second toe, now points inside the great toe, or even over the center of the internal border of the foot (Fig. 2419).

It has been stated that under normal conditions, in the act of passive weight bearing, the astragalus rotates downward and inward upon the os calcis, depressing its anterior and internal border until the movement is checked by the strong ligaments connecting the bones (the calcaneoscaphoid, the deltoid, and the interosseus); in other words, the leg has a tendency to slip downward and inward from off the foot. In the typical weak foot this inclination has become an accomplished fact, for the normal movement has become so exaggerated by the distention of the ligaments and by the weakness of the supporting muscles that a partial dislocation has taken place (Figs. 2420, 2421). The astragalus has rotated and slipped far to the inner side of its normal position and is in an attitude of exaggerated rotation and moderate plantar flexion, so that its head can be plainly felt on the internal border of the foot. The anterior extremity of the os calcis is depressed and turned slightly inward and its internal border is lowered. The scaphoid bone is lowered together with the head of the astragalus, although to a less degree, and has been forced farther away from the os calcis, and with it the entire border of the foot is depressed also. Thus the depression of the arch, the third element in the deformity, is always preceded and accompanied by a bulging inward of the inner side of the foot. The foot is, as it were,

broken in the center, the posterior division having turned inward and downward; that is, the astragalus has rotated inward and downward to an extreme degree and has slipped from off the os calcis. The latter bone, although forced outward in its relation to the astragalus, still turns inward slightly, while the fore foot in its relation to the leg and to the posterior divisions of the tarsus is greatly abducted. The dislocation may be so extreme that the entire sole of the foot rests upon the ground, and a callus even may be found at the point that usually represents the highest point of the arch, which now supports the greatest burden.

In this change of relation between the bones, the arched part of the foot, or waist, appears much broader than normal, even broader than the front of the foot; the heel projects, the external malleolus is depressed and carried forward by the rotation of the leg and is much less prominent than normal: the internal malleolus is more prominent and with the astragalus it overhangs the bearing surface of the sole. The foot, considered as a mechanism, is twisted and out of gear, its motion is therefore very much restricted. It is manifestly impossible for the patient to adduct the fore foot, that is, to turn it inward about the head of the misplaced astragalus. Plantar flexion is also much limited because of the permanent position of adduction and plantar flexion that the astragalus has assumed. Dorsal flexion, on the other hand, may appear to be abnormally free, because the fore foot is abducted and slightly dorsiflexed upon the head of the astragalus. When, however, the displacement is reduced adaptive shortening of the calf muscle becomes evident in many instances.

Supposing the foot to have been normal before it began to break down, it is apparent that such deformity could not have been acquired without adaptive changes in its internal structure. In a general way these changes have been indicated by the description; the ligaments on the internal aspect of the foot and of the ankle-joint are weak and distended; the unused portion of the articular surfaces of the joints may be denuded of cartilage, while new facets may have formed to accommodate the changed relation of the bones—as, for example, at the junction of the external malleolus with the os calcis. Evidence of injury and of abnormal pressure may be found in thickened periosteum and in formation of osteophytes, while the internal structure of the bones has been changed as well, to adapt itself to the new conditions. The muscles which are no longer used in the leverage function, the plantar flexors and adductors, have become atrophied—a change that is most evident in the shrunken calf. The muscles on the inner border of the foot have been over-stretched, while those on the upper and outer part have become shortened and contracted. Such a foot represents an extreme, it may be an irremediable, degree of deformity. The machine is completely broken down; it can no longer perform its proper function; it is even less efficient than the wooden foot, because use is attended by discomfort.

The disability and deformity are found in every grade of severity. Pain begins when the muscles are over-strained by the disadvantageous attitude. Later, when the bones are habitually placed in abnormal relation to one another, the accommodation and nutritional changes advance. It is evident therefore that the individual in whose foot the arch is accentuated and whose ligaments are firm, may suffer from the symptoms of strain long before the arch has been depressed or deformity has become apparent; also that the lateral inward bulging, characteristic of advancing deformity, must in such a case be very great before the astragalus can reach the ground and the arch be completely flattened. On the other hand, if the individual has inherited a low arch, or if, as the result of weakness in early life, the arch has been depressed or has never developed, accommodative changes in the bones will have taken place during growth, so that the flat foot of this type will not be attended with as much change in its relation to the leg, and therefore disturbance of function, as in the typical case that has been described. This latter class of cases exemplifies the popular type of flat foot that may exist without pain or disability.

It is very evident that the lowering of the arch is a secondary element of the deformity and that the popular significance of flat foot, as an inherited and irremediable weakness, is most misleading. It is misleading also in that in the most painful type of weak foot there may be practically no lowering of the arch, as shown by an imprint of the sole, while the actual flat foot may exist without symptoms.

As has been stated, there is one feature common to every grade of the so-called flat foot: the foot regarded as a machine is weak, as compared with the normal standard—weak because of the persistence of the attitude of rest and relaxation, as contrasted with that of activity and strength, and weak because the proper relation between the power and the fulcrum is changed. Even the inherited flat foot, or the flat foot which has never caused symptoms, is weak, in the sense that in use it lacks the spring and elasticity characteristic of the perfect machine.

The term weak foot may be used then to indicate all types of the disability. In one weak foot the arch has disappeared; in another weak foot the arch is of normal depth, but the foot is abducted in its relation to the leg. In one case the deformity appears only under weight; in another the foot is held rigidly in the deformed position by muscular spasm. In one instance there may be great deformity without pain; and in another disabling weakness and pain without deformity. In one case the foot is unable to perform its functions because of its inherent weakness, in another the disability may be due simply to the improper use of a normal structure. In all cases, however, disability as exemplified by the symptoms of pain and weakness is due to a disproportion between the burden or strain that is put upon the foot and the ability of the mechanism to perform this task.

This theory accounts for the fact that the weak foot, although very common in childhood, does not, as a rule, cause discomfort until adolescence, when the weight and strain put upon it are increased. It explains also why the foot which may be fairly normal in structure breaks down more often in later adolescence or early adult life when the continuous strain of regular occupation is undertaken. It is evident that an occupation requiring the long continuance of the passive attitude—that of waiters, cooks, and bartenders for example—exposes the feet to greater strain than one which permits alternation of postures, and that the symptoms are likely to be more severe and the deformity to be greater among those who are obliged to labor than among those who are not. Overwork or strain, of occupation or otherwise, may be temporarily disproportionate because of local or general weakness, as for example during pregnancy or after recovery from exhausting disease or because of local injury or disease of the foot itself or simply because of the strain of more constant use. On this theory one may very easily explain why weak foot may appear or rather attract attention at any age, and why also there is no constant relation between the degree of deformity and the severity of the symptoms; for although all presenting the characteristic deformity are weak feet, yet all weak feet are not necessarily painful feet. Pain is not caused because the foot is flat; it is a symptom of progressive deformity, of strain and injury to the joints; it shows that the foot is becoming flat; it is a symptom of the injury that the weak or flat foot has received. The progress of the deformity may be temporarily or permanently checked at any stage, either by a removal of the excit-

ing cause or because of the resistance of the tissues; then the pain ceases. On the other hand, this stability may not be attained until the entire sole of the foot rests upon the ground, and even then the patient may suffer from discomfort and pain.

This conception of the foot as a machine, of which grades of efficiency may be recognized, has a great advantage, since it enables one to perceive wherein a foot is weak even though the weakness causes no symptoms whatever. Thus one may prevent deformity by avoiding the extra strain that improper attitudes entail, and by strengthening the muscles on whose ability its integrity depends. Finally, from this standpoint one may better appreciate the etiological importance of improper shoes, in this as in practically all of the disabilities to which the foot is liable.

As has been stated, the symptoms of the weak foot, although similar in type, vary in severity according to the local condition and the disturbance of function, the work to be performed, and the susceptibility of the individual.

Symptoms.—The most characteristic symptom is the sensation of weakness. The patient begins to recognize as familiar, a feeling of discomfort, of tire and strain about the inner side of the foot and ankle, sometimes after long standing, a dull ache in the calf of the leg, or pain at the knee, hip, or in the lumbar region, symptoms more common in women than in men; or, after overexertion, a momentary sharp pain radiating from the point of weakness; thus the patient often dates the history of his trouble from a long walk. After a time the patient may become aware that he is accommodating his habits to his feet; he rides when he once walked; he sits when he once stood; he no longer runs up or down stairs or jumps off the street car. His feet have lost their spring as he expresses it, which means that the foot is no longer supported and controlled by muscular activity and is no longer used as a lever. Not infrequently, early symptoms are pain and sensitiveness at the center of the heel, explained in part by the jarring heel walk which is always assumed when the foot is weak, and in part by the strain upon the attachments of the deep plantar ligaments. The patient may complain that he cannot buy comfortable shoes; the reason is that the weak foot under use changes its shape, so that the shoe that was comfortable in the morning compresses the foot painfully at night. Thus increasing discomfort, due in part to corns, bunions, painful great toe joints, and deformities of the toes, is experienced. Coldness and numbness, congestion and increased perspiration, caused by the impaired circulation and weakness, are common symptoms in cases of the more advanced type. Actual pain is, as a rule, felt only when the foot is in use. It ceases under temporary rest or relief from disproportionate work, and it is this remittence of symptoms, together with the fact that discomfort is usually more marked in damp weather, that leads so often to the mistaken diagnosis of rheumatism. The foot is weak and vulnerable; the patient recognizes the fact that he has what he speaks of as a weak ankle, or sprain, or gout, or rheumatism; but if he has accommodated himself to the weakness, but little discomfort is experienced. In many instances such relief or accommodation is impossible, and it is therefore among the working class that one oftener sees the rapid development of the disability and deformity. The range of motion becomes more and more restricted; the habitual attitude, at first exaggerated to deformity only under the influence of the weight of the body, becomes a permanent displacement. The weak and distorted foot is subjected to constant injury, to what may be likened to a succession of slight sprains; thus local congestion, swelling, and sensitiveness may appear together with muscular spasm and pain on passive motion. Because of the stiffness of the foot, and the consequent loss of accommodation to inequalities of the surface, the patient dreads to cross a rough pavement, for every misstep is a source of pain. Another characteristic symptom is the discomfort felt on changing from a position of rest to activity. The patient after sitting, or on rising in the morning, is unable to walk, but staggers and limps for several minutes, a symptom explained by the fact that when the foot is at rest there is a partial reposition of the displaced bones, which must be again forced into the deformed posture that has become habitual. The local sensitiveness and stiffness are increased by use, so that the patient may have difficulty in removing the shoe at night, and the symptoms relieved by the rest of Sunday become progressively worse during the week.

The pain and discomfort in cases of this type become more general in character, and are often referred to the dorsum of the foot, representing muscular spasm and tension, to the irritated plantar fascia, and to the outer side of the ankle, where the external malleolus is grinding out a facet in the projecting os calcis. The patient may now complain of discomfort in the feet and of cramps in the legs, even when in bed, and the appearance of weakness, awkwardness, and depression of spirits may be so noticeable that the case is sometimes mistaken for serious disease of the nervous system.

The appearance of such a foot has already been described, and the effect of the deformity on its function should be evident. The gait is slouchy and cloddy; the feet are simply pushed by one another in the attitude of eversion, the knees are slightly flexed and the weight is borne entirely upon the posterior segment of the foot. The muscles have atrophied, the foot is cold and congested from its continual inactivity, and it usually is bathed in perspiration. A certain range of motion remains at the ankle joint, but adduction is absolutely restricted by the shortened and spasmodically contracted muscles on the outer and upper surface. This type represents of course only the severe variety that is more likely to be seen in hospital than in private practice; and it would seem, were it not for the evidence to the contrary, which the histories of the patients present, that the nature of the trouble must be recognized at a glance, although in the milder and earlier cases the diagnosis is not always so easily made.

Fig. 2422.—Extreme Deformity in Adolescence.

Diagnosis.—In all cases in which weakness of the foot is suspected, a thorough and orderly examination should be made, not only of its appearance, but also of its functional ability and of the manner in which it is used. Such an examination is not merely for the purpose of confirming a diagnosis which is usually evident on inspection, but rather that the amount and character of the temporary or permanent changes in structure may be estimated.

Attitudes.—One begins the examination by noting the manner of standing and walking. The heel walk, the exaggerated turning out of the feet, the slouchy gait in which the leg is never completely extended, in which the power of the calf muscle is not applied and in which the essential postures of the foot are disused, are all elements of weakness that should be corrected whether they cause symptoms or not. The distribution of the weight of the body and the habitual use of the foot are often made evident by examining the worn shoe. If it is bulged inward at the arch or worn away on the inner side of the sole, it shows weakness.

Fig. 2423.—Voluntary Dorsal Flexion.

The same observations are then made on the bare feet, particular attention being paid to the line of strain or leverage. Thus, a line drawn down the crest of the tibia from the center of the patella continued over the foot, should meet the interval between the second and third toes; if it falls over or inside the great toe, it shows that the foot is working at a disadvantage.

The contour of the foot should then be examined. Its internal border should curve slightly outward, so that if the feet are placed side by side with the toes and heels in apposition, a slight interval remains between the arches; if this slight concavity is replaced by a noticeable convexity when weight is borne, the foot is weak. This change in contour is the earliest and sometimes the only evidence of deformity. The arch of the foot properly protected by the muscles and by a proper attitude, sinks but slightly under weight; there is a slight elasticity only, as the strain is thrown more to the inner side of the median line, and if the depression is marked it shows weakness.

Fig. 2424.—Voluntary Plantar Flexion.

Bearing Surface.—The exact amount of bearing surface may be shown by an imprint upon carbon paper or by smearing the sole with vaseline; then as the patient stands upon a sheet of white paper the outline of the foot should be traced, so that the relative size of the imprint to that of the foot may be shown and compared with the normal standard. This is however a test of no diagnostic value but simply indicates the degree of deformity in certain types of cases.

The Range of Motion.—The range of motion is next to be tested, for its limitation is one of the earliest signs of disuse of function and weakness. This range of motion varies somewhat within normal limits; it is usually greater in childhood than in adult life, greater in the slender than in the massive foot, and greater in the foot used properly than in one that is not. The first test is applied to simple dorsal and plantar flexion; the leg must be fully extended at the knee, the line of strain must be in its normal relation so that the foot is neither adducted nor abducted, and the observation must be made upon its outer border. The patient should be able to flex the foot from ten to twenty degrees less than the right angle, and to extend it from forty to fifty degrees beyond the right angle, the range of motion being from fifty to sixty degrees.

Fig. 2425.—Voluntary Adduction.

By far the most important test, however, is that of adduction or inversion of the foot, the range of motion at the mediotarsal and subastragaloid joints. With the leg extended as before, the foot is turned inward as far as possible. The elevation of its inner border (supination) and the turning in of the heel are shown in the accompanying figure. The actual range of adduction is somewhat difficult to measure, but it is about thirty degrees (Fig. 2425). Even the mild and early cases of weak foot usually show some limitation of this most important motion because of disuse, and in many instances it is completely lost, the patient turning the entire leg in the effort to adduct the foot. The less important range of abduction may then be tested; normally it is about half that of adduction. It may be noted that the range of supination or inversion of the sole is nearly twice as great as that of pronation or eversion of the sole; in other words, the internal bor-

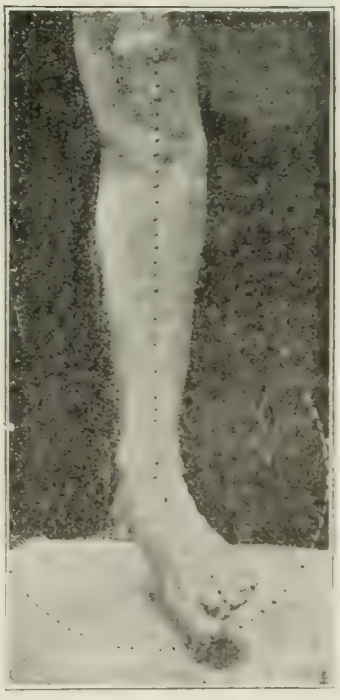


Fig. 2426.—Voluntary Abduction.

der of the foot can be raised twice as far from the floor as can the external border.

The range of passive motion is then tested. That of dorsal flexion is from five to ten degrees beyond that of voluntary motion, while passive extension, so far as it applies to the ankle joint, is about the same as the voluntary, although the fore foot may be still farther bent downward at the mediotarsal joint. The limits of passive adduction and abduction are considerably beyond those of the voluntary range.

The test of passive motion serves several purposes; contrasted with the range of voluntary motion it indicates the habitual use of the foot, since the motion lesst used is most limited. It also makes evident the slight restriction of motion and the presence of local sensitiveness, which, even in early cases, are usually present. Thus, if pressure be made just in front of and below the internal malleolus, at the astragalo-scaphoid junction, and if at the same time the foot be suddenly adducted, the patient will complain of pain at the point of pressure and of a feeling of constriction and tension about the dorsum of the foot, before the normal limit of motion is reached. When the foot is dorsiflexed the plantar fascia is put upon the stretch, and its condition may be noted, for a contracted and sensitive plantar fascia may cause symptoms of disability that induce, or are combined with, abduction and valgus. In other words, this mode of examination demonstrates the disability and permanent change in the machine which must be overcome before a cure can be accomplished. By it one will recognize several grades of weak foot.

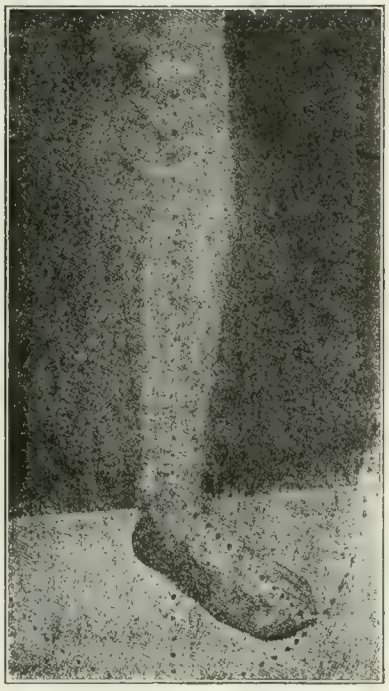


Fig. 2427. The Attitude of Weakness that Predisposes to Disability and Deformity.

Varieties of Weak Foot.—1. The normal foot improperly used, as shown by the manner of standing and walking.

2. The foot which, because of laxity of ligaments or insufficient muscular support, is forced by the weight of the body into an attitude of deformity. The foot when in use falls into an abnormal attitude of abduction in its relation to the leg, as evidenced by the inward projection of its inner border and by the overhanging internal malleolus, showing that the leg has been displaced inward on the foot. As a rule, in this class, the laxity of ligaments allows a depression of the arch, as shown by the imprint, but in other instances, although the arch seems lower because of the characteristic attitude (valgus) in which the leg as it were overhangs the foot, yet the imprint shows that there is no increase in the area of bearing surface. Indeed this may be even smaller than normal; thus an individual may suffer from so-called flat foot whose arch is in reality exaggerated.

3. The weak foot, which shows typical deformity under use and in which the range of voluntary motion is somewhat limited, particularly in the direction of plantar flexion and adduction. In this class forced movement causes discomfort and pain, showing a certain permanent accommodative change in structure which is not apparent when the foot is not in use.

Fig. 2428.—Weak Foot in Childhood showing Habitual Abduction without Depression of the Arch.

Fig. 2429.—Extreme Deformity in Adolescence; Abduction and Complete Sinking of the Arch.

In these slighter grades of disability, the improper use of the foot, the loss of active leverage ("spring") is very evident when the patient walks.

4. The foot which presents typical and permanent deformity, whether it is in use or not, and in which the range of both voluntary and passive motion is much restricted.

This limitation of motion is an adaptation of structure to the habitual functional use and to the deformity. Such changes are first apparent in the muscles and ligaments; in more advanced cases, the articular surfaces of the bones are altered to accommodate the habitual subluxation. Added to this underlying limitation of motion there is usually a certain amount of muscular spasm, which varies in degree with the local congestion, irritation, and inflammation of the joints and tissues. In the quiescent weak foot it may be absent, but on renewed injury or overwork of the weak structure it again appears. It depends also upon the irritable condition of the overworked and contracted abductor muscles, practically the only group that retains functional power. Thus the spasm, as has been stated in describing the severe and painful type of weak foot, is greater after the day's use and relaxes somewhat during the night. The degree of muscular spasm and rigidity varies with the intensity of the symptoms. It is often greater in the early stage of the disability than in the cases in which the deformity is of long duration.

Two Extreme Types of Weak Foot.—1. *Persistent Abduction.*—In one type of rigid foot, the foot is twisted outward and upward. It may be inverted to such an extent that practically the weight is borne upon the heel and ball of the great toe. In such instances the astragalus, although rotated inward upon the pronated os calcis, is, of course, not plantarflexed nor is the anterior extremity of the os calcis depressed. The entire foot is simply held in an attitude of extreme abduction and slight dorsal flexion, by the spasm and contraction of the flexors and abductors, so that the leg must be bent at the knee and inclined forward to bring the sole to the ground. Such extreme cases are uncommon. They are often the direct result of injury ("chronic sprain"), and when the deformity is reduced the arch will be found to be exaggerated in depth. Less extreme types of this class are often seen and they serve to emphasize the statement that the most important disability of the weak foot is due to the change from the normal relation between the leg and the foot (valgus) and not to the depression of the arch (planus) which is, in most instances, a secondary deformity.

Fig. 2430.—Adduction of the Fore Foot Combined with Valgus; an uncommon type.

2. *Pes Planus.*—As has been stated already and as is well known, there is a type of painless deformity sometimes called pes planus. To this type the term flat foot may be properly applied because the flatness of the foot is more noticeable than the other components of the deformity that have been described. This class is probably the effect of inherited laxity of ligaments or of rachitis or other form of acquired weakness in early life, so that a normal arch was never present. Such a foot controlled by efficient muscles may be strong and serviceable, but it is nevertheless deformed, and it is doubtful if its possessor ever could attain the grace and elasticity of gait possible under normal conditions. It is said also that a low arch is normal in certain races, for example the negro, but it is certain that the American negro is not exempt from the pain and disability incidental to the broken-down foot, whether his arch was originally low or not.

It is evident that the breaking down of a properly shaped foot, provided with normal ligaments, must be attended by greater pain and disability than of one in which the arch was originally low and of which the ligaments were weak, because it is during the progression of the deformity, and particularly in its early stages, that such symptoms are most prominent. When the bones of the arch rest upon the ground or when final stability has become assured, pain may cease, and permanent accommodation to the new condition may increase the ability of the deformed member. Such an adaptation might be quickly accomplished in the foot originally flat, while in the other instance the symptoms, although remitting from time to time, might continue during the life of the sufferer.

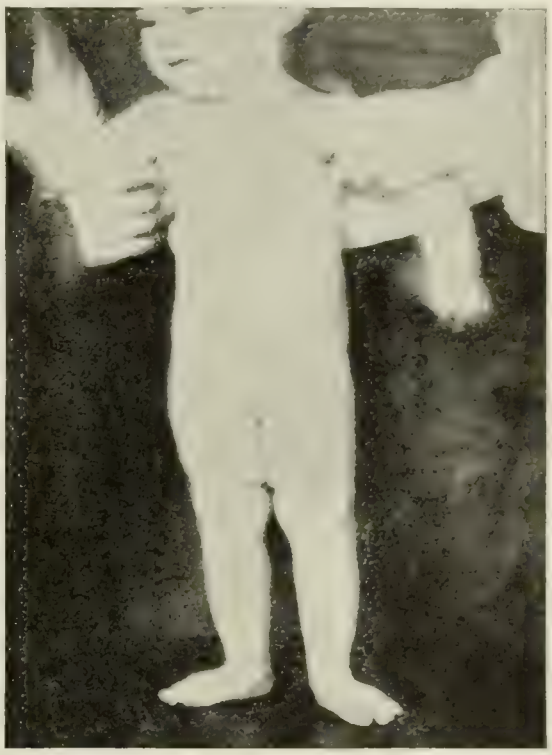


Fig. 2431.—"Flat Foot" showing the Extreme Abduction in Early Childhood.

Weak Foot in Childhood.—There can be no doubt that in many instances the origin of the weak foot may be traced to early childhood. Certainly, deformities and improper attitudes are very common at this period and it is much more likely that they are ingrown than outgrown. Actual pain from the weak foot is unusual at this age. The child may complain of fatigue and may be weak and awkward, but it is usually because of the very evident deformity, rather than because of symptoms, that advice is asked. In these cases, as in every case, the habitual attitudes and use of the feet are of the first importance.

One of the most frequent of the improper postures is that of exaggerated outward rotation of the limbs, which is not only an ungraceful attitude, but a direct cause of weakness as well. The opposite attitude of

inward rotation of the feet, the so-called "pigeon-toed" walk, is most offensive to relatives and friends, and it is for correction of the attitude that the child may be brought for treatment. The attitude is, in most instances, a sign of the weak foot, for on examination the bulging on the inner side, the inward rotation of the leg in its relation to the foot, and the flattened arch, show very plainly that it is the foot and not the attitude that requires treatment; in fact the attitude is, in this class of cases, really a safe-guard against increasing deformity and it will correct itself when its cause is removed. Particular emphasis is laid upon this point, which is very generally overlooked, because the routine treatment of the "pigeon toes" in these cases might be the cause of direct harm.

"Weak ankle" is a term popularly applied to the weak foot of childhood, in which the foot is in a position of valgus when in use, so that the shoe is worn away on its inner side. Weak ankles are very common in very young children and are often one of the results of general weakness due to defective assimilation. At this age the foot is, in addition, usually flat, although in the valgus or weak ankle of later years the arch is often normal in outline.

In older children prominent or "outgrown" joints often attract the mother's attention; the internal malleoli appear prominent because of the position of valgus, or, because of the eversion of the feet, the malleoli may strike against one another, "interfere," and thus there may be an actual hypertrophy of the tissues over the projecting bones from local irritation.

Another type is the long slender foot in which the scaphoid bone is prominent because of the strain and pressure put upon it by the improper attitudes; its position is often shown by the point of wear in the leather of the shoe. In the weak foot of childhood, although restriction of voluntary and passive motion may be present, there are, as a rule, but little local sensitiveness and muscular spasm, and as has been stated, but little pain. Thus it differs greatly from the adult type, the reason being that the weak foot in childhood is not subjected to the strain of constant occupation or to the burden of disproportionate weight. There is another important difference also: the foot in the adult is obliged to bear a greater burden than any other part, and although fairly normal in structure it may be overstrained. Thus in many instances the weakness of the foot may be the only disability. In childhood, on the other hand, a weak foot is very often a local indication of general weakness and loss of tone.

It must be borne in mind that the feet are the foundation of the body, and that an insecure foundation affects the entire mechanism. General functional weakness and awkwardness, the flat chest, round shoulders or other curvatures of the spine, are often observed as accompaniments or effects or weak feet. Thus, the systematic treatment of any form of postural weakness in childhood must often include the treatment of the feet as well.

Recapitulation.—The disability and deformity of the weak or so-called flat foot are caused by disproportion between the strength of the foot and the weight and strain to which it is subjected.

The foot may be weakened by injury or disease; it may be overburdened by the body weight, or overstrained by laborious occupation, or the broken-down foot may be simply one indication of general bodily weakness. It is unnecessary to enumerate all the various factors that singly or combined lead to this disability.

It may be stated, however, that the painful weak foot as seen in adult life is in many, or most, instances the only evidence of weakness. The most constant of the predisposing causes are improper shoes, and the mechanical disadvantage to which the foot is subjected by the assumption of improper attitudes.

All weak or flat feet are mechanically weak, but all weak feet are by no means painful feet. Pain, the symptom of overstrain or injury, bears no definite relation to the degree of deformity.

In certain instances, exaggeration of the arch may be combined with persistent abduction of the foot; in others, the flattening of the arch may be the most noticeable deformity, but in most cases, the two are combined in varying degree. And as each deformity is an evidence of weakness, it seems hardly necessary to made a radical distinction between the two.

Treatment.—The principles of the treatment which leads to the permanent cure of the weak foot are very simple, but their application varies somewhat according to the grade and duration of the disability. The object of treatment is so to change the weak foot that it may conform, not only in contour but in habitual attitudes and in power of voluntary motion, to those of the normal foot, because cure is impossible until function is regained. The first step must be, therefore, to make passive motion free and painless to the normal limit. In other words, the obstructions to the motion of the machine must be removed before the power can be properly applied; for normal function is manifestly impossible, while motion is restrained by deformity orpain or by adhesions or contractions.

The weak foot, because of inefficient muscles unable to hold itself in proper position, must be supported, in many instances, until regenerative changes have taken place in its structure. Such support is necessary to retain the joints in proper position, and to hold the weight and strain in normal relation to the foot. When these essentials are provided, the patient may cure himself by the proper functional use of the foot, and by the avoidance of attitudes that place it at a disadvantage.

Fig. 2432.—The Proper Relation of the Sole to the Shape of the Foot. *A*, Outline of sole: *B*, outline of foot; *C*, imprint of foot.

It may be well to describe first the treatment that must be applied to all classes of weak foot in which a cure is to be attempted, and which by itself is sufficient in the milder types, before calling attention to the modifications that may be necessary in special cases.

The Shoe.—In practically all cases it will be necessary to provide the patient with a proper shoe, for the shoe is usually the direct cause of the minor deformities, and the indirect cause, in many instances, of more serious disability. Indeed most of the deformities and disabilities of the foot are incidental to civilization and are confined to the shoe-wearing people.

The direct effect of the ordinary shoe is to lessen the size and balancing power of the fulcrum by cramping the toes together while the high heel throws more strain upon the arch and the ankle. Indirectly it causes deformities, corns, bunions, and the like, which make active movement or leverage painful, and induce the habitual assumption of the passive attitude which predisposes to deformity.

The proper shoe should contain sufficient space for

the independent movements of the toes. This motion is illustrated in the walk of the barefoot child. As the weight falls on the foot the toes expand, and as the body is raised on the foot they contract. The important leverage action of the great toe and the support afforded by it to the arch of the foot have already been mentioned. The shape of the sole should correspond to the shape of the undistorted foot. The heel should be broad and low and the shank narrow and flexible.

The prevention of distorted toes and the discomforts that result from the abuse of the foot is of great importance in childhood, but, unfortunately, little children are often seen wearing shoes of the shape usually assumed at years of discretion. In this regard, girls suffer more than boys, as women do more than men. The girl who may have worn comparatively harmless shoes until the age of ten years or thereabouts, changes suddenly to the high heel and narrow sole and the process of distortion begins, the character of distortion and the degree of discomfort depending on the amount of work required of the foot. Shoes without heels should be worn as long as possible by children because of the greater stability and because the high heels limits the necessity for, and therefore the use of, the entire range of motion of the foot and ankle. These shoes should however conform to the shape of the foot in the manner described.

A simple expedient in the treatment of the weak foot and an aid in balancing it properly, is to make the inner border of the sole and heel of the shoe slightly thicker in order to throw the weight toward the outer side of the foot. This is of especial importance in the treatment of the slighter degrees of what is known as weak ankle, but it is always of service in the treatment of any grade of weak foot.

Attitudes.—When the patient is provided with a proper shoe, his attention is called to the attitudes that

Fig. 2433.—The Internal Border of the Shoe Elevated According to Thomas' Method.

protect the foot from strain. He should endeavor to hold the feet nearly parallel to one another in walking and to throw the weight as far as possible on the outer border of the sole of the shoe. The significance of the bulging on the inner side of the foot is pointed out to him and how this may be prevented by voluntarily inclining the weight to the outer side of the foot and by aiding the arch by the power of the great toe.

The importance of leverage is explained. He is told that he must try to press down the sole of the shoe with his toes and employ the active lift of the calf muscles by fully extending the leg and raising the body on the foot from time to time. Finally, he must avoid especially the passive posture which simulates the attitude and deformity of flat foot by inclining the weight toward the outer border of the foot in standing. In short, he must be instructed in the mechanics of the foot and taught how the weak foot may be protected and strengthened.

Fig. 2434.—Illustrating Voluntary Protection of the Foot from Overstrain. Compare with Fig. 2427.

Exercises.—Voluntary exercise should be devoted to strengthening the adductors and plantar flexors; thus the foot should be extended, adducted, and supinated over and over again at every opportunity. Tip-toe exercises are particularly useful. The patient holding the feet parallel to one another, or better in inward rotation, raises the body on the toes from twenty to one hundred times, the limbs being fully extended at the knees, resting in the intervals on the outer border of the feet. The best of all exercises is, however, the proper walk, in which at each step the leverage power of the foot is employed and in which it passes through the proper alternation of postures.

Treatment by massage and special gymnastic exercises is, of course, of benefit, if the patient can command it, although by no means essential to the cure.

Support.—In many instances the simple treatment that has been outlined is all that is required and the symptoms of tire and strain are quickly relieved. In the more advanced type of disability the patient is not able to prevent deformity voluntarily; consequently a support is necessary to hold the foot in proper position and to relieve discomfort. It is usually necessary in the treatment of the weak and flat foot of childhood, because one cannot command the aid of the patient.

A support for the weak foot should be adapted to the nature of the deformity. The deformity is not a direct breaking down of the arch, as is usually taught, but a lateral deviation and secondary depression. Consequently the support should be primarily lateral and it should not interfere with normal function upon which cure depends.

The supports that are ordinarily employed do not fulfil the conditions; the pads and springs placed beneath the arch are intended to support it by direct pressure without regard to the lateral distortion; they are usually ill-fitting and are often of such length and shape as to splint the foot and thus prevent its motion. Leg braces which more directly control the valgus do not often hold the foot accurately, and their weight and unsightliness are fatal objections to their use in the early cases, in which prevention of subsequent deformity is of such importance.

A brace should never be applied to a deformed and rigid foot because it is not able to shape itself to the support; the spasm and rigidity must first be relieved by preliminary treatment, as will presently be described.

The Construction of the Brace.—The first essential is a plaster cast of the foot, taken in the attitude in which one wishes to support it. Such a model may be easily and quickly made in the following manner:

The Plaster Cast.—Seat the patient in a chair; in front of him place another chair of equal height; on it lay a thick pad of cotton batting and cover it with a

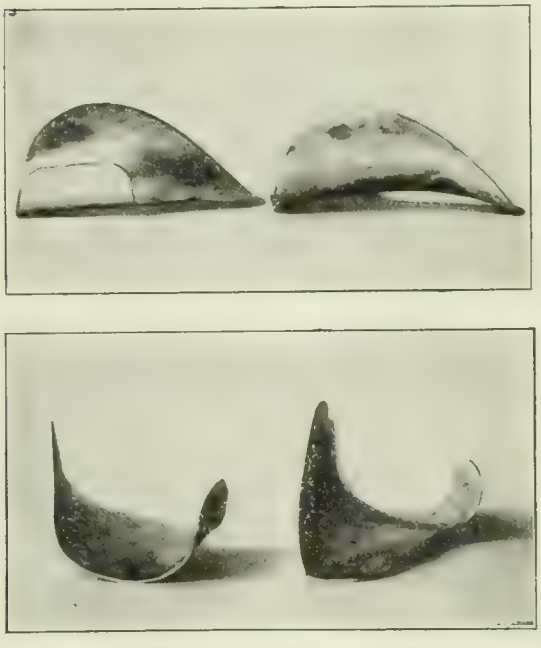


Fig. 2435.—The Steel Brace Seen from Various Aspects.

square of cotton cloth. Put about a quart of cold water into a basin and sprinkle plaster of Paris on the surface until it does not readily sink to the bottom; then stir. When the mixture is of the consistence of very thick cream pour it upon the cloth. The patient's knee is then flexed and the outer side of the foot, previously powdered lightly, is allowed to sink into the plaster, and the borders of the cloth being raised the plaster is pressed against the foot until rather more than half is covered. The foot should be slightly plantar flexed to correspond to its attitude in the shoe and the sole should be in the plane perpendicular to the seat of the chair. As soon as the plaster is hard, its upper surface is dusted with talcum powder and the remainder of the foot is covered with plaster; the two halves are then removed, rubbed with talcum, and bandaged together. The mould is then filled with the plaster cream. In a few moments the plaster shell may be removed and one has a reproduction of the foot, which, when properly made, should stand upright without inclination to one side or the other. In most instances it will be of advantage to deepen in the plaster model the inner and outer segments of the arch, especially at the heel in order to restore the normal contour and usually a little plaster is added to the outer border which may have been flattened by pressure.

The Brace.—Upon the model, the outline of the brace is drawn as illustrated in the diagrams. The best sheet steel, eighteen to twenty gauge, cut after

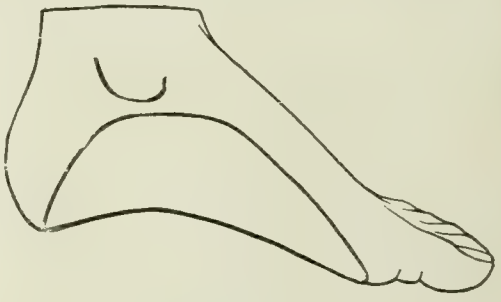


Fig. 2436.—Showing the External Arm of the Brace as Applied to the Foot.

the pattern is moulded upon it and tempered, so that, as it is applied for the purpose of preventing deformity, it may be practically unyielding to the weight of the body. It is then polished and galvanized to prevent rusting.

It will be noted that the brace clasps the weak part of the foot and holds it well together; the broad internal upright portion covers and protects the astragaloscaphoid junction, rising well above it. The external arm covers the calcaneo-cuboid junction and the outer aspect of the foot to a height sufficient to hold the foot securely. The sole part provides a firm, comfortable support, which does not press upon the sole because the foot is inclined toward the outer border and because the lateral restraint prevents the sinking of the arch. Finally as the brace extends only from the center of the heel to a point just behind the metatarsophalangeal joint of the great toe, it does not restrain the normal motions of the foot.

As it is fitted to the foot it finds and holds its own place in the shoe, so that no attachment is required; thus it may be changed from one shoe to another. Not only does it hold the foot laterally and from beneath, but there is an element of suggestiveness in the slight leverage action which is very important.

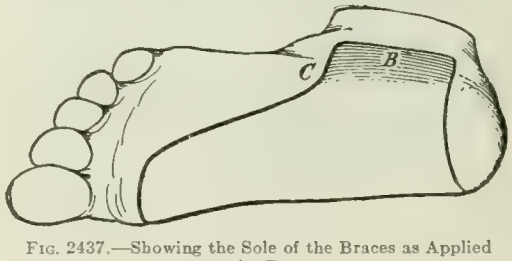


Fig. 2437.—Showing the Sole of the Braces as Applied to the Foot.

The patient, instructed to throw his weight upon the outer side of the foot and wearing a shoe which has been tilted in the same direction by thickening the inner border of the sole and heel, presses down the external arm and thus lifts the internal flange against the inner side of the foot, which is instinctively drawn away from the pressure and thus toward the normal contour. Thus he no longer rotates the limbs outward, everts the feet in walking, or assumes the passive attitude in standing because of the suggestive lateral pressure of the support. This brace is therefore,

when properly adjusted, a positive aid in the physiological cure as contrasted with the negative action of the ordinary sole plate.

The shape of the brace, in general like that of the diagram, may be modified in certain cases; for instance, the entire internal aspect of the foot may be weak as, for example, in those exceptional cases in which the greatest deformity is in front of the astragaloscaphoid articulation and must be covered by the internal flange. In very heavy subjects the sole portion must be made wider and if metatarsal support is required it must be extended forward beneath the

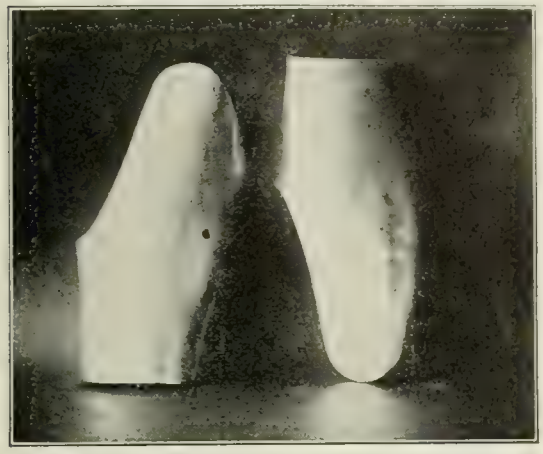


Fig. 2438.—Wide Supports for Very Heavy Persons.

joints. If any portion of the rim of the plate causes discomfort, as shown by an indentation in the skin the edge may be turned away slightly at the point of pressure by a wrench. At first it is often necessary to remove the brace at intervals, but when it has been adjusted and after the patient has become accustomed to the new postures and attitudes it is worn constantly. It is usually necessary to wear it for from three months to a year or longer, according to the condition of the part and the use to which the feet are put. The brace, properly made and adjusted under the proper conditions, causes no more pressure or discomfort than a well-made shoe, for its principle is quite different from that of ordinary supports that are in common use, to which this objection has been made. This brace supports the arch primarily by preventing abduction, consequently its pressure is first felt upon the lateral aspect of the foot, a pressure that the patient can relieve by improving the attitude. The brace should provide support when necessary, and at all times suggest and enforce a proper attitude; it is, however, but one of the essential factors in the general scheme of treatment.

In the treatment of children, passive movements of the foot should be carried out in all directions, but particularly in dorsal flexion and adduction to the full limit, at morning and at night, until the child has regained the normal muscular power and ability. Special gymnastics and massage are always desirable and they may be necessary in certain cases. Bicycling may be cited as one of the best, and roller skating as one of the worst, exercises for the weak foot. A year is about the time required for the cure of the ordinary type of weak foot in childhood, although attention to the shoes and the attitudes must be kept up indefinitely.

The Rigid Weak Foot.—One may now contrast with these mild types of weakness that have been described, those cases of extreme deformity in which the symptoms are disabling and in which the foot is rigidly held in the deformed position by muscular spasm. Such cases, often considered hopeless as regards a cure or even relief, are in reality the most satisfactory from the remedial standpoint, and in no other type of painful deformity can so much be accomplished by rational treatment as in this class. The deformity must be considered as a dislocation, in which the astragalus has slipped downward and inward from off the os calcis, which in turn is tipped downward and inward and into a position of valgus. The remainder of the foot is turned outward, so that the relation of the fore foot and the leg is entirely changed; in fact the fore foot is almost entirely disused.

Corresponding to the duration of the disability, one finds the accommodative changes in the soft parts and in the bones, but such changes are by no means as marked as those recorded in the reports of autopsies which have been made in cases of advanced and irremediable deformity. In fact, by far the greater number of patients are young adults in whom the extreme deformity is of comparatively short duration, and in whom complete cure is possible.

In the treatment of such a condition, one must first reduce the dislocation and overcome the obstacles that contracted muscles and ligaments may offer to free and normal motion. Then rest must be assured to the injured and congested parts in order to relieve the patient from the pain that he has suffered so long.

Forcible Overcorrection.—By far the most effective treatment is forcible overcorrection of the deformity, under anesthesia. When the patient is under the influence of the anesthetic the muscular spasm relaxes, and it will be seen that this accounts for about half the restriction of motion, the remainder being caused by the adaptive changes that have been mentioned. One now endeavors to overcome this residual obstruction and to assure the patient against a relapse, by fixing the foot in the position of extreme adduction and inversion, the attitude directly opposed to that which has become habitual.

This is the object of forcible overcorrection as the first step in the systematic repair of the disabled mechanism. Its principle must not be confounded with forcible correction carried out with the object of simply remoulding the arch of the foot, or in which the simple correction of the deformity is the object in view.

One first extends the foot forcibly, then flexes it to the normal limit, then abducts and adducts, the different motions being carried out over and over, until the rigid foot has become perfectly flexible. In cases of long standing it is often necessary to draw the patient to the end of the table so that the foot may be taken between the knees, in order to supply the required force by the thigh muscles. This forcible manipulation is accompanied by the audible breaking of adhesions, and the complete disappearance of the deformity. In certain instances it will be necessary to divide the tendo Achillis; when, for example, the range of dorsal flexion is limited by resistant accommodative shortening of the calf muscles, or when because of great pain and sensitiveness at the mediotarsal joint, it is desired to remove the strain of the calf muscle completely; traumatic cases come especially under this head. In other cases the peronei tendons may be divided if they offer especial resistance to adduction. Tenotomy has one great advantage: it necessitates longer fixation in the plaster bandage, and gives the patient the benefit of rest and the opportunity for prolonged after-treatment. When the passive range of motion has been regained, the foot is turned downward, then inward and upward into the position of extreme varus. By this manipulation the os calcis is drawn under the astragalus and thrown into the supinated position, and the scaphoid is flexed about and under the head of the astragalus, which is then lifted to the limit of normal flexion. The attempt is always made to bring the extreme outer border of the inverted

foot up to a right angle with the leg, which is the limit of normal flexion in this attitude. The foot, thickly padded with cotton, especially about and between the toes, is then fixed in this position by a firm plaster-of-Paris bandage extending to the knee. Surprisingly little discomfort, considering the force that it is sometimes necessary to apply, is experienced after the operation. The familiar and often intense pain, from which the patient has suffered so long is entirely relieved by the correction of the deformity; there is of course a sense of tension about the outer side of the ankle and dorsum of the foot, but this is not, as a rule, of long duration.

Functional Use in the Overcorrected Attitude.—As soon as possible, often on the following day, the patient is encouraged to stand and to walk. Walking serves two purposes: to still further overcorrect the deformity, and to accustom the patient to a posture entirely different from that so long assumed. Meantime the contracted tissues on the outer side become thoroughly overstretched, the weakened ligaments and muscles on the inner side are relaxed, and the local irritation rapidly subsides under the rest from the constant injury to which the foot has been subjected. The patient is not confined to the bed or house, although if both feet are in plaster supports, crutches are of course necessary. The time that the feet should remain in the overcorrected position depends upon the duration of the deformity and the severity of the symptoms, the usual time being two

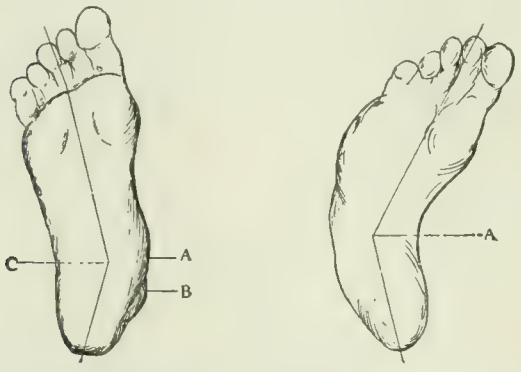


Fig. 2439.—Illustrating Forcible Correction of the Deformed Foot. *C*, Mediotarsal joint; *A*, the scaphoid bone; *B*, the internal malleolus.

weeks to a month or more. When the patient can use the foot without discomfort the plaster support is removed; the foot is placed in the normal attitude and a cast is taken for the brace. Immediately after the foot is returned to the former position, and the plaster bandage is reapplied. When the brace is ready this is finally removed; the foot is now in good position, and in many instances the arch is exaggerated in depth. For the first few days, prolonged soaking in hot water or the use of the hot-air bath, with subsequent massage, at intervals during the day, will be found useful in overcoming the swelling and local tenderness that may persist. It is always insisted that a new shoe of the proper shape shall be obtained, the sole and heel of which are raised a quarter of an inch on the inner border, to aid the action of the brace in the balancing of the weak foot. When the shoe is removed at night, the patient is instructed to invert the foot until it has regained its strength; in other words, the deformity is never allowed to recur.

Systematic Manipulation.—The systematic treatment is then begun by the surgeon and the patient, the first essential being the attainment of free and painless passive motion in all directions. These motions, which have been so long restrained by deformity, cannot be regained without effort, and during this critical stage treatment must be carried out by the surgeon himself; if he trusts to the patient or to his friends, a cure is out of the question. At least once a day the full range of motion is tested. Three motions, abduction, flexion, and extension, are usually free and painless; but the fourth, that of adduction, is almost invariably resisted by the same quality of muscular rigidity that was present before the operation. By far the most effective method of overcoming this resistance is conducted as follows. The patient being seated in a chair, the surgeon sits or stands before him. Let us suppose that the left foot is to be adducted, or, as the patients express it, twisted. The surgeon places the foot between his knees; his left hand encircles the heel, the fingers grasping the projecting oscalcis and tendo Achillis; the ball of the palm lies against the mediotarsal joint on the inner aspect of the foot; the right hand grasps the outer side of the fore foot and toes; then by steady pressure of the thigh muscles, the fore foot is forced downward and inward (adducted and supinated) over the fulcrum formed by the projecting palm which lies upon the left knee, the fingers holding the heel steadily in place. This inward twisting is at first resisted by a mixed voluntary and involuntary muscular spasm, which gradually gives way under steady pressure. When the limit of adduction has been reached the foot is firmly held until all pain has subsided. Then the patient is instructed to attempt voluntary movements while the foot is guided by the hands; in other words, the patient attempts to adduct the foot while the surgeon supplies the power, which, in all cases of this type, has been completely lost. In most instances and especially in hospital practice the deformity is restrained in part by the application of adhesive plaster strapping applied in a manner presently to be described. This passive manipulation to the extreme limit of normal adduction, plantar and dorsal flexion, is continued from day to day until there is no longer a sensation of pain or tension; for as long as there is the slightest spasm or pain on passive motion, so long is the muscular control limited, cure delayed, and relapse of deformity probable. During active treatment the patient, by the use of massage, active and passive motion, is constantly working to one end, namely, to regain the lost power of voluntary adduction.

The time necessary to rest the feet, to overcome the local irritation and muscular spasm, to regain, in part at least, the range of passive motion, and to place the patient in the same position as regards a cure as that of the milder type of deformity, is from three to six weeks. Usually the patients are told that a month will be necessary, and that at the end of that time they may return to work, free from pain and from danger of relapse, and that the feet will constantly grow stronger under the work which before was too great for their strength. The time necessary to re-educate the adductor muscles in their proper function depends, in great degree, upon the intelligence and persistence of the patient. Although in after-treatment massage and special exercises are of benefit, the essentials are very simple; they are, an effective brace, a proper shoe, and the passive manipulation that has been described, until its object has been attained; the proper walk, the best and easiest of exercises; and finally, one must force into the patient's understanding the method of protecting the weak foot by the alternation of strain and by the proper postures.

Other Varieties of Rigid Weak Foot.—The foot which is fixed in the abducted position without depression of the longitudinal arch, is simply one variety of the rigid weak foot, and should be treated in the same manner.

It may be stated also that a very large proportion of the so-called chronic sprains of the ankle are of this type, and that the disability will yield very readily to treatment conducted for the purpose of restor-

ing impaired function, in the manner that has been indicated.

There are other cases in which the deformity of flat foot is a complication of arthritis deformans or chronic rheumatism or gout, of which the evidence is seen in various joints, but in which the pain and discomfort seem to be concentrated in the feet, which are stiff and deformed. In such cases one can hardly expect complete relief, but although the function of leverage may not be regained, still one may hope, by overcoming the deformity, to hold the weight of the body in its proper relation to the foot, so that the pain of a progressive dislocation may not be added to the pain of disease. In a number of instances, forcible correction has been employed by the writer in cases of this type, and in all the improvement in the general condition, consequently in the resistance to the disease, after the relief of the local pain and discomfort, has been very great.

Between the two classes of cases, the mild and the severe, one finds every grade of deformity. All cases in which there are marked muscular spasm, local tenderness, and swelling, require temporary rest, in many instances simply rest from functional use combined with massage; in others rest in a plaster bandage in the adducted position. In the milder and ordinary class of cases, the use of a brace and shoe will alone relieve spasm and pain, and the range of motion can usually be regained by manipulation, passive motion, and by the proper use of the foot.

Occasionally, even in childhood, one may encounter marked limitation of normal motion, particularly in dorsal flexion, not due to pain and muscular spasm but to actual shortening of muscle. This may be the accommodative shortening that is characteristic of long-standing deformity; in other instances it would appear to be the result of a slight and unnoticed neuritis or anterior poliomyelitis, which has resulted in muscular inequality. If the contraction does not yield readily to manipulation or to mechanical stretching, forcible correction, and if necessary tenotomy, should be employed in the manner already described; for whatever may be the theory of its causation, it is again emphasized that obstruction to motion in any direction must be overcome before a complete cure is possible.

Adjuncts in Treatment.—It must be apparent that in many instances the cure of the weak foot is out of the question, either because of the want of energy or opportunity on the part of the patient, or because of the local or general conditions, types familiar in outpatient practice. In such cases, raising and strengthening the inner side of the shoe by the wedge-shaped leather sole, as used by Thomas, splints the painful foot and aids in relieving the strain. If the symptoms are more acute the adhesive plaster strapping is often of service, although it is applied in a different manner, and with a somewhat different object in view. One end of a strip of adhesive plaster, about fifteen inches long and three inches wide, is applied to the outer side of the ankle just below the external malleolus; the foot is then adducted as far as possible and the band is drawn tightly beneath the sole and up the inner side of the arch and leg, and is stayed in this position by one or two plaster strips about the calf. Narrow plaster straps are then applied about the arch and ankle, in the figure-of-eight manner, and a bandage is applied. The object of the dressing is to aid in holding the foot in the proper position by the support and suggestiveness of the plaster, and to provide the firm compression about the arch that is always agreeable to the sufferer from weak foot. This treatment combined with the built-up shoe, and with the corrective manipulation that has been described, is often very effective in overcoming the acute and disabling symptoms of the weak and injured foot, which are, as has been stated, often the result of extra strain or injury, in other words, a sprain of a weak foot. Consequently when these symptoms are relieved, the patient who has become habituated to the weakness and deformity, considers himself cured.

Operative Treatment.—The various cutting operations for the relief of flat foot do not call for extended comment and they are employed only in cases of extreme and resistant deformity. The typical operation, the removal of a wedge of greater or lesser extent from the astragaloscaphoid region, aims at removal of deformity simply; functional cure is made impossible by the destruction of the mediotarsal joint. The operation of advancement of the posterior extremity of the os calcis, as proposed by Gleich, in order that it may be placed in a relation to the leg somewhat like that of a Pirogoff amputation, offers little hope of ultimate cure, for as the disability is not due to primary depression of the arch, it can hardly be cured by exaggerating its depth in this manner. The most rational of the operations for flat foot is the supramalleolar osteotomy of Trendelenburg, in which the bones of the leg are divided above the ankle, and the distal fragment is turned inward, with the aim of directing the weight upon the outer border of the foot. In practice, the operation is by no means always successful, while the bow-leg deformity that results, if the object is attained, is an unfortunate accompaniment of the treatment.

It may be mentioned in this connection that fracture at the ankle joint, followed by faulty union in a position of valgus, is a form of traumatic flat foot that may be cured by this operation. In estimating values of operative treatment, the rest, necessary for weeks or months, must be considered as explaining in part the immediate favorable effect of whatever procedure is adopted.

II. The Hollow or Contracted Foot. (Talipes cavus; Talipes plantaris.).—The hollow foot in which the arch is exaggerated may be considered as the condition directly opposed to the flat or relaxed foot in

Fig. 2440.—The Contracted Foot—An Exaggerated Arch and Slight Limitation of Dorsal Flexion.

which the arch is lessened or lost. In the latter instance the area of bearing surface is increased while in the hollow foot the bearing surface is diminished and the imprint of the sole may show that the entire weight is borne upon the heel and upon the metatarsophalangeal region.

The contracted foot may be divided into two classes, the simple and the compound. In the first class the

arch alone is exaggerated, "Talipes arcuatus." In the second there is a limitation of the range of dorsal flexion at the ankle joint as well, "Talipes plantaris." A mild form of this type was originally described by Shaffer under the title of "Non-Deforming Clubfoot" (*Medical Record*, May 23, 1885).

Etiology.—The simple hollow or high-arched foot may be an inherited peculiarity. It may be induced by the habitual use of high heels or possibly by excessive exercise of the calf muscle as by professional dancers.

Those cases in which there is limitation of the range of dorsal flexion at the ankle joint, or even slight persistent equinus, may be congenital also, but in most instances it appears to be a remote effect of a temporary weakness of the dorsal flexors of the foot, or of restriction of dorsal flexion from some other cause. This supposition is supported by the fact that the symptoms may date from a period of weakness and awkwardness following scarlet fever, rheumatism, or other infectious disease of childhood, symptoms attracting little attention in early life, but becoming more marked in adolescence or at a later period. In other instances the cause may be more direct, the slight deformity following a sprain or fracture, or it may be a result of an habitual attitude, as in patients who have been treated for disease of the hip joint by the traction appliance.

Symptoms.—The simple contracted foot may not cause symptoms; in fact it often passes as a particularly beautiful member rather than one that is deformed. As a rule, however, the patient complains of inability to buy well-fitting shoes, as the ordinary shoe does not support the arch while the upper leather presses uncomfortably upon the prominent dorsum. In cases of this type there may be actual exostoses on one or more of the projecting cuneiform bones of the dorsum surmounted by a sensitive bursa.

There is usually, in consequence of the rigidity of the foot, abnormal pressure upon the heel and fore foot, and sensitive corns or callosities at the latter point are often found. Pain beneath the great toe-joint or about the anterior metatarsal arch, which is often depressed, is a common symptom, and as a rule patients complain of discomfort in the hollow of the foot referred to the tense and sensitive plantar fascia. The gait is usually ungraceful, the patient everting the feet and walking heavily upon the heels. In many instances there is a persistent attitude of valgus, "weak ankles," and in cases of this type the most troublesome symptoms may be those characteristic of the weak foot. The symptoms described are usually more marked in the compound variety of the contracted foot than in the simple form.

On examination the nature of the affection is usually apparent. The arch is exaggerated, especially on the inner border, and the tense contracted bands of plantar fascia, usually very sensitive to pressure, can be demonstrated when the foot is dorsiflexed. In many instances there is an obliteration of the anterior metatarsal arch, the normal slight concavity being replaced by a distinct convexity, and at, or about, the head of the third metatarsal bone a sensitive callus is usually present. The toes are usually contracted that is hyperextended at the metatarsophalangeal, and flexed at the first phalangeal articulations. The prominence of the dorsum of the foot corresponds to the depth of the arch, and at this point, as has been stated, one or more of the cuneiform bones may project sharply beneath the skin. The range of dorsal flexion is often restricted at the right angle with the leg, and in this class there is usually habitual dorsiflexion of the toes, as if the direct result of the action of the accessory dorsal flexors of the foot.

Treatment.—In the mild cases of simple hollow foot the symptoms may be relieved in many instances by the use of a properly fitted shoe with a high "Spanish" arch.

If the symptoms are more persistent, a metal foot plate, modelled upon a plaster cast of the sole, may be employed, the object of the brace being to equalize the pressure on the sole, to remove the strain upon the sensitive fascia, and to lessen the pressure on the sensitive points of the anterior metatarsal arch. If the foot is habitually used in a valgus attitude, the sole and heel of the shoe must be made thicker along the inner border in order to correct the inclination.

In addition to the supporting shoe or brace, daily forcible manipulation, with the object of stretching out the foot and increasing the range of dorsal flexion, if this be limited, and of restoring the range of plantar flexion of the toes, is of service.

If the deformity is well marked and of long standing it should be corrected by operative means. The patient being anesthetized the plantar fascia is divided subcutaneously and the exaggerated arch is then reduced to the normal depth by forcible manipulation with the hands, or by the use of the Thomas wrench. The limitation of dorsal flexion is overcome by stretching or if necessary by tenotomy of the tendo Achillis. If, as in the more extreme cases, the contraction of the toes is resistant, the deformity is overcome by force and if necessary the extensor tendons are divided. The foot is then placed in moderate dorsal flexion, the metatarsal arch being elevated by forced plantar flexion of the extended toes and fixed by a plaster support, the sole part being thick and unyielding, and the foot is fixed in a plaster bandage in which a thin wooden foot plate is incorporated. The patient is afterward encouraged to walk in order to still further flatten the yielding sole by the weight of the body. A metatarsal foot plate is afterward applied and combined with persistent manual stretching, voluntary efforts will usually restore a sufficient range of plantar flexion of the toes to overcome the deformity of the metatarsal arch by flattening the sole against the resistant sole plate.

III. Plantar Neuralgia.—Pain referred to the hollow of the foot, combined with sensitiveness to pressure on the plantar fascia, is usually symptomatic of the hollow or contracted foot in which the fascia is subjected to abnormal tension. Occasionally it is present when the arch is weak or broken down. Sensitiveness of the fascia and pain at this point on standing are sometimes present in feet apparently normal. These symptoms may be induced by injury or by irritation or inflammation of the fascia, apparently due to infection, as it may follow influenza, typhoid fever, and the like.

Treatment.—If the foot is fairly normal in appearance, or if slight weak foot is present, the application of a well-fitting shoe may relieve the symptoms. In most instances, however, a properly fitted light steel foot plate is indicated, in order that the weight may be distributed, thus relieving the fascia from strain. If the foot is markedly contracted the fascia may be stretched or divided. (See Contracted Foot.)

IV. Weakness of the Anterior Metatarsal Arch. (Anterior Metatarsalgia; Morton's Neuralgia.)—Pain and discomfort referred to the metatarsophalangeal articulations of the foot are symptoms that may be explained in most instances by weakness or deformity of the metatarsal arch. Normally the anterior extremities of the metatarsal bones, although each bears its share of weight when pressure is put upon the foot in standing and walking, form an arch when the foot is not in use, the second and third bones being on a somewhat higher level than the others. In other words, there should be a certain resiliency of this part of the foot that lessens the liability to injurious pressure or strain. In many instances this resiliency is lost and one finds on examining the sole of the foot a persistent convexity in place of the normal arch. It may be noted in this connection that plantar flexion of the toes raises the heads of the adjoining

metatarsal bones and increases the metatarsal arch. On the other hand, dorsiflexion of the toes lowers the arch, and as this attitude of persistent dorsiflexion of the first phalanges and consequent limitation of plantar flexion is one of the common effects of improper shoes, one recognizes the shoe as the most constant cause of weakness and of depression of the metatarsal arch.

Another type of weak arch is that in which there is, in consequence of weakness and flabbiness of tissue, an abnormal lateral expansion of the fore foot. Or again there may be apparently a local weakness of the muscles or ligaments of one of the component bones of the arch that allows it to assume an abnormal relation to its fellows.

Attention was first called to pain in this region of the foot by Dr. T. G. Morton of Philadelphia, in 1876, under the title of a painful affection of the fourth metatarsophalangeal articulation, and as far as the symptoms of this type of what may be called anterior metatarsalgia is concerned, his description needs but little amendment. Typical cases of this class are characterized by a sudden cramp-like pain beneath the fore foot in the neighborhood of the fourth toe. It may begin as a burning pain beneath the toe or isimply as a sensation of discomfort that gradually ncreases until it becomes unbearable. From the point of greatest discomfort the pain often radiates to the end of the toe or up the dorsum of the foot to the leg. Except in extreme cases, the pain is never felt except when the shoe is worn, and it may be relieved usually by removing the shoe and rubbing the foot. This need is so urgent that the removal of the shoe is one of the most distinctive signs of the affection. These cramp-like attacks may occur only at infrequent intervals, as for example when a certain shoe is worn, or they may recur so frequently as practically to disable the patient. After an attack of cramp the part may be sensitive for a time, and swelling even may appear, if it has been severe and prolonged. This is, however, rather unusual. The affection is relatively more common among women than among men, and among the well-to-do rather than the poorer classes. It is not infrequently found in several members of the same family, and it may be an inherited peculiarity. It is often bilateral, the second foot becoming affected usually after a considerable interval. The affection is usually chronic in character and not infrequently the patients are of a nervous or possibly neurasthenic type.

As has been stated, pain, although far more common at the fourth articulation, is by no means confined to this point. In some instances the patient is unable to localize the pain accurately, in others it is referred to the three adjoining toes, second, third, and fourth. In certain cases the greatest complaint is of sensitiveness of the metatarsophalangeal joints to pressure, either direct or lateral. This complaint is more common when the arch is depressed and fixed in this attitude corresponding to the rigid weak foot. In other instances a painful callus beneath the second or third metatarsal head is the chief source of discomfort.

It should be stated that typical cases of Morton's neuralgia may be present although the foot is apparently normal in appearance.

Etiology.—The attacks of pain, although favored by "hot pavements," by "the sticking of a damp stocking to the foot," by thin soles, by sudden and unguarded movements, and the like, are practically always induced by the shoe, and it may be assumed that the pressure of the shoe upon a weakened and sensitive part induces the cramp. The influence of the shoe, as the author has suggested elsewhere (*Medical Record*, August 6, 1898) may be explained as follows. Normally, lateral pressure on the hand or foot compresses it and increases the depth of the arch, as the tight glove does the hand. If, however, this increase of the arch is prevented, the adjoining bones cannot escape direct lateral pressure, a pressure that then becomes extremely painful, as one may demonstrate upon one's self by squeezing the hand suddenly while the metacarpal bones are fixed in the same plane; or if one finger of the hand be dorsiflexed so that the metacarpophalangeal joint is forced below the level of its fellows, pain on lateral pressure is always referred to this point. The same maneuver causes pain in the foot at the corresponding articulation. It is evident also that in the foot an articulation that is depressed habitually will be constantly subjected to greater weight, or direct pressure as well, when it is in use.

Of all the causes of weakness and deformity of the anterior part of the foot the shoe is by far the most important. The lateral compression of the narrow and ill-shaped sole induces distortion of the toes and atrophy of the muscles that have lost their function. Thus the fore foot, deprived of its accessory supports, is subjected to abnormal pressure. The depression of the metatarsal arch is induced by the persistent dorsiflexion of the toes which is the attitude of shoe-wearing people, an attiude favored by direct compression by the rocker shape of the ordinary shoe and by the slight depression of the sole beneath its center.

In the depressed arch, that metatarsophalangeal joint that is lowest is subjected to abnormal pressure and it is liable to lateral compression as well, the latter being the direct cause of the characteristic cramp. The fourth articulation is that most liable to injury because it is practically the outer support of the arch, as the fifth joint is almost always on a higher plane or in an attitude that favors injurious pressure.

This may be readily illustrated by the school boy trick of suddenly compressing the hand when the fifth metacarpal bone is above the level of the fourth.

Fig. 2441.—An Attitude of the Hand in which Lateral Pressure is Painful.

In many instances of Morton's cramp there seems to be simply a laxity of tissues that allows a sudden displacement downward of the fourth articulation or elevation of the fifth, a movement as of something slipping in the bone which is followed by the characteristic pain. This displacement may be induced by a misstep or by overexertion and not infrequently the first appearance of the affection dates from a sprain or twist of the foot, or is induced by extreme dorsiflexion of the toes. It may be stated also that extreme dorsiflexion may cause a subluxation of one of the joints which in itself may be the cause of the peculiar pain. There are, of course, other predisposing or exciting causes of this pain than the simple local causes that have been mentioned: for example, weakness of the longitudinal arch, the hollow foot, in which the plan-

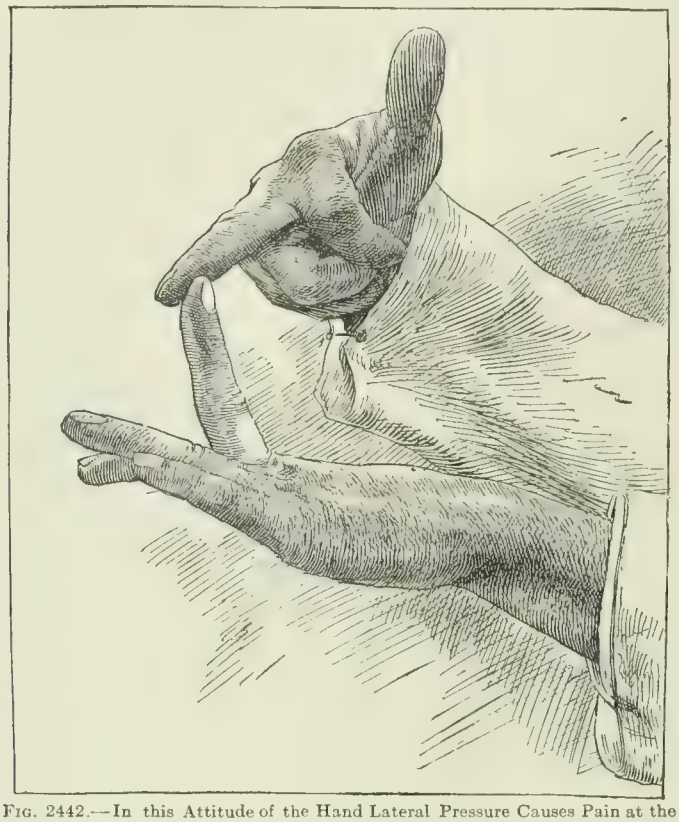


Fig. 2442.—In this Attitude of the Hand Lateral Pressure Causes Pain at the Depressed Joint.

tar fascia is contracted: gout, rheumatism, or other local or constitutional affection that may make the foot abnormally sensitive.

Pathology.—It would appear, as has been stated, that the ordinary cause of the symptoms is pressure, which, as the attacks recur, makes the articulation in general sensitive. The more intense pain is due apparently to injury and pressure on a digital nerve and in certain instances a local neuritis may be present. Other changes in and about the joint are usually those secondary to the abnormal position of the part.

Treatment.—The treatment should be conducted with the aim of removing the direct causes of the discomfort and of restoring the normal condition of the weakened part. The first essential is therefore to provide the patient with a proper shoe. This must correspond with the outline of an undistorted foot; the sole should be thick and the shank should be arched to give proper support to the sole. A laced shoe that may be drawn tight about the arch usually adds to the comfort of the patient. The sole should be flat and it should be somewhat thicker in the center so that it may form a slight convexity beneath the metatarsal arch. In fact the object of mechanical treatment is to support this anterior arch in its proper position. For this reason it is well in most instances to provide the patient with a light steel sole plate, fashioned on a plaster cast of the sole of the foot, of which the longitudinal and anterior arches have been somewhat exaggerated. This plate, as is shown in the diagram, usually extends from the center of the heel to slightly beyond the metatarsophalangeal joints, but in certain instances it is of advantage to extend it farther forward in order to splint the foot and prevent dorsal flexion of the toes if this motion induces discomfort or if the part is especially sensitive and if the longitudinal arch is weak it should be supported by a combination brace of the type mentioned in the description of the weak foot. As an immediate treatment the fore foot from the tarsus to the phalanges may be bound by strips of adhesive plaster, the metatarsal region being compressed somewhat as a tight glove compresses the hand; the elevation of the arch may be further assured by inserting a pad of felt or leather beneath it. This is a very effective means of relieving the discomfort and preventing the recurrent cramp.

In acute cases or when the part is very sensitive, and particularly in those cases that have resulted directly from injury, a plaster bandage may be applied, the foot being fixed in an attitude of slight dorsiflexion and adduction. The metatarsal arch should be exaggerated and the toes fixed in slight plantar flexion. If the arch is rigidly depressed, as in certain cases complicated by rheumatism and the like, the deformity must be overcome by forcible manipulation under anesthesia before the bandage is applied.

In all cases the patient should endeavor, in the after-treatment, to regain power of plantar flexion of the toes by manipulation and by exercise, and by pressing the toes firmly against the sole of the shoe to assist, as far as may be, the weakened arch in the performance of its labor.

Operative Treatment.—An effective treatment, and one that may be necessary in the persistent type of this affection, is excision of the head of the metatarsal bones, if, as is usual, the pain is localized at this point. This operation, the treatment of routine suggested by Morton, is easy of performance and it usually affords relief. The resulting deformity is but slight. In most instances it is, however, unnecessary.

Thus far cases resembling the Morton type have been considered. There is another class in which the metatarsal arch is uniformly depressed and in which the toes are contracted. The fore foot is thickened and the patient complains of discomfort on standing and often of burning pains at night. In many instances the pain is aggravated by a sensitive callus beneath the arch. In curative treatment a foot plate is applied but the range of plantar flexion is increased by methodical forced flexion of the toes in order that the flexibility of the region may be restored. In resistant cases forcible connection under anesthesia may be necessary

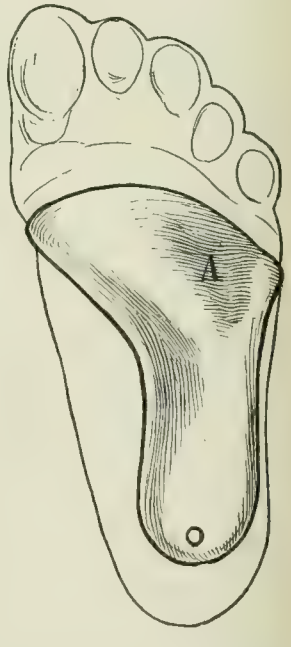


Fig. 2443.—A Brace to Support the Anterior Arch. *A*, The point of greatest elevation beneath the painful part.

and in instances of extreme deformity resection of the depressed metatarsal heads may be necessary.

Massage, the hot-air bath, and the application of various liniments are of some service in certain cases as adjuncts. Constitutional treatment is also indicated in those cases in which there is a gouty or rheumatic tendency or other complication.

V. Hallux Rigidus (Hallux flexus).—Hallux rigidus is a painful affection of the great toe joint accompanied by restriction of motion. In well-marked cases the toe may be habitually plantar-flexed to a slight degree; hence the name hallux flexus suggested by Davies-Colley. In this class the motion may be much restricted, particularly in dorsal flexion, thus interfering with proper functional use of the foot. There is usually pain of a burning, throbbing character referred to the joint and increased by use, and a certain degree of congestion is often present.

Etiology.—Hallux rigidus is usually seen in adolescence as a complication of a weak arch which allows the fore foot to be crowded into the narrow part of the shoe, thus subjecting the great toe joint to lateral and longitudinal pressure. In some instances the habitual flexion is the effect of an instinctive effort of the

Fig. 2444.—Plantar Flexion of the Toes. An exercise for strengthening the anterior arch and overcoming deformity.

patient to support a weakened arch by downward pressure of the great toe. (Hammer-toe, flat-foot, Nicoladoni.)

The affection may also be induced directly by injury, as by stubbing the toe or by kicking a hard object, or it may be a complication of rheumatism or gout.

There are no distinctive changes in the joint other than those secondary to long-standing restriction of function and deformity.

Treatment.—If the rigid joint is a secondary effect, as in most instances it is, of the weak or broken-down foot, the first step is the treatment of the exciting cause (see Weak Foot). In any event a properly fitting shoe must be worn, which exerts no pressure on the sensitive part. The sole must be thick, so that movement in the joint may be restricted, and in certain instances it may be necessary to insert a steel brace between the layers of the sole of the shoe in order to prevent all motion for a time. If direct pressure on the toe joint causes discomfort, the sole of the shoe may be made very thick just behind the sensitive part, so that the weight is supported as it were on an anterior heel (Fig. 2445).

If the affection of the toe complicates a rigid weak foot, as is not infrequently the case, the deformities should be overcorrected under anesthesia (the flexed toe being forcibly extended), and fixed in a plaster bandage in the manner described in the section on Weak Foot. In extreme, and very exceptional, cases of long standing, excision of the joint may be required.

Fig. 2445.—The Anterior Heel.

VI. Painful Great Toe.—Pain, on motion and pressure, at the great toe joint, and symptoms resembling those of hallux rigidus, are not uncommon in older subjects. These symptoms are induced usually by a long walk or by strain or other injury.

The treatment is based upon essentially the same principles as those governing the treatment of the former affection. Thus, for example, splinting may be employed, when necessary, to restrain painful motion, and a proper shoe may be fitted for the relief of pressure.

Pain about the great toe is a common symptom of the weak arch, or of the contracted foot. It may be caused simply by the pressure of a tight shoe. It is often present as a symptom of hallux valgus and of its accompanying bunion. The joint may be directly involved in gout, rheumatism, and the like, and an enlargement of the metatarsal extremity by an outgrowth of cartilage or other change in conformation similar to that observed in the fingers (Heberden's nodes) is not uncommon. The treatment must be directed to the cause. Resection of the metatarsal extremity may be advisable, if pressure on the enlarged joint causes discomfort.

VII. Hallux Valgus.—Hallux valgus is a deformity of the foot, in which the first metatarsal bone is adducted and at its anterior extremity separated from its fellows, while the toe is turned outward or abducted to a greater or less degree. Thus although the area of the toes is contracted the fore foot is actually broadened.

In consequence of the distortion there is an actual displacement of the joint surfaces. In marked cases, the first phalanx of the distorted toe articulates only with the external condyle of the metatarsal bone, while the internal condyle, projecting on the inner side of the foot, is subjected to the direct pressure of the shoe. Here a bursa forms and this in turn is surmounted by a corn or callus.

The projecting condyle, sometimes irregular and hypertrophied by the deposit of periosteal bone, the bursa, and the overlying corn make up the enlarged joint or so-called bunion. In cases of this type there is usually more or less abduction of the other toes, and the great toe, often rotated on its long axis, may be displaced above or below its fellows.

Etiology.—By far the most important of the predisposing and exciting causes of the deformity, and of the consequent pain and discomfort, is the shoe. In fact a moderate degree of hallux valgus, shown by the projecting "enlarged" joint, is so common as to pass as the normal condition of shoe-wearing people. The influence of the shoe is increased when the longitudinal arch is weak, as the parts are then subjected to greater pressure. The deformity, or more especially the symptoms, may be increased by gout, rheumatoid arthritis, and the like, and by overstrain and injury as well.

Pathology. The pathology does not call for extended comment. There are the usual changes in

and about the joint that accompany similar subluxations, the cartilage disappears from the exposed parts of the internal condyle, and the ligaments and the muscles contract on the shortened side and oppose the rectification of the deformity.

Symptoms.—The most important sign of hallux valgus is the deformity. The most important symptoms are the pain and sensitiveness induced by the pressure upon the projecting joint. The discomfort is, of course, greatly increased by the inflamed bunion and accompanying corn. There may be pain also beneath and about the joint. Pain in the joint may be in part symptomatic of the irritation and changes secondary to the deformity itself. Pain beneath the joint is usually caused by the greater pressure to which the part is subjected by the outward rotation of the foot, an attitude that is almost always assumed by the patient if there be an accompanying weak foot. In certain instances pain beneath the joint may be due to irritation about one of the displaced sesamoid bones, which are sometimes adherent and are sensitive to direct pressure.

Treatment.—In the slighter degrees of deformity the symptoms may be checked by the use of a proper shoe, straight on the inner side and with capacious upper leather. This removes the direct pressure and allows an opportunity for normal movement. Making the sole somewhat thicker on the inner border is of advantage also, as it inclines the weight slightly toward the outer part of the foot. In addition, daily manual correction of deformity, together with alternate voluntary flexion and extension of the toe while it is guided by the fingers in the normal direction, is of advantage from the curative standpoint.

A number of appliances have been devised to hold the toe in normal position while the foot is in use. In most instances, however, the incidental discomfort is sufficient to prevent their use. One of the simplest and most efficient of these devices is the Holden toe post, a thin upright of metal fixed in the front of the sole of the shoe, making a compartment into which the toe is guided and thus held in an improved position. This toe post necessitates a digitated stocking and a special shoe; like other appliances it is very uncomfortable unless it is perfectly adjusted, and until the patient has become accustomed to it.

It must be borne in mind that a part of the deformity of hallux valgus is caused by the adduction of the metatarsal bone. It is well, therefore, to lessen this displacement by the use of a bandage or by adhesive-plaster strapping about the fore foot, so applied as to exercise a certain amount of compression at this point.

It has been stated also that weakness of the arch or flat foot is a common accompaniment of hallux valgus. In such cases a proper support is an essential part of the treatment.

As a rule patients demand treatment rather because of the discomfort than because of the slight degree of deformity. This discomfort is due to the pressure on the sensitive bunion lying on the projecting condyle, and the removal of this projecting bone will practically relieve the symptoms.

A simple and effective operation is conducted as follows. A slightly curved incision is made below the joint, the bunion is dissected from the adherent skin, the joint is opened and the projecting bone, usually the greater part of the internal condyle of the metatarsal bone, smoothly removed with a chisel, after which the capsule is closed with fine catgut as in the external wound. The toe is then straightened by stretching the contracted tissues. The entire foot is slightly adducted, or turned inward, and together with the leg is enclosed in the plaster, the toe being fixed in the corrected position by the same means.

As soon as the weight can be supported without discomfort the patient is allowed to walk about on the foot. Afterward, manipulation, exercises, the use of a proper shoe together with a flat-foot brace, if this is indicated, will complete a practical cure.

Modifications of the Operation.—In certain instances there may be contraction of the extensor tendon of the toe. Weir has suggested that this may be divided and sewed to the periosteum on the outer border of the first phalanx, thus serving to prevent recurrence of deformity.

In more extreme cases of contraction and deformity, resection of the head of the metatarsal bone may be indicated. Cuneiform osteotomy of the metatarsal bone has been suggested, but this, to be effective, must include the projecting condyle.

Fowler's Operation.—In this procedure the incision is made between the first and second toes, the ligament is divided, and the toe is displaced inward. The bunion and the projecting portion of the internal condyle are then removed if necessary, the toe is replaced, and the wound closed. This operation appears to offer no advantage over the simple one that has been described, for, when properly performed, the scar is insignificant and is not subjected to pressure if it be made slightly below the most prominent part of the joint.

Bunion—The treatment of the bunion, the inflamed sac and corn, may be summarized as rest with hot or cold applications during the active stage, with relief of pressure by the use of a proper shoe. In many instances a metallic support for the arch to remove the direct pressure on the toe is indicated. Operations should as a rule be deferred until the acute symptoms have subsided. An effective operation must include the removal of the projecting bone as well as the sac.

VIII. Hallux Varus and Pigeon Toe.—The term hallux varus is properly applied only to persistent adduction of the great toe, while pigeon toe is the popular name for in-toeing, an attitude usually caused by an inward rotation of the entire limb.

Hallux varus is usually congenital: the great toe turns inward, sometimes when in active motion, to a marked degree, in fact it may be almost prehensile in its movements.

In certain instances there is slight accompanying adduction of the foot at the mediotarsal joint, constituting a mild degree of talipes varus. The mother's attention is usually attracted to the condition, not by an actual deformity of the toe, but by difficulty in putting on the baby's stocking.

Hallux varus is occasionally seen also as an acquired peculiarity in connection with certain varieties of weak foot (valgus). In such cases there is a marked inward bulging at the mediotarsal joint which is compensated for by an exaggerated inward twist of the fore foot and adduction of the great toe (Fig. 2430).

Treatment.—Simple hallux varus, as a rule, requires no treatment since it is cured by the use of the shoe when the child begins to walk. In more extreme cases the prehensile movements may be restrained by a narrow band of adhesive plaster passed over the toes and fore foot. If talipes varus is present it should be treated in the ordinary manner (see *Foot, Distortions of the*).

Pigeon Toe.—Hallux varus is a rather unusual cause of the in-toeing gait, or so-called pigeon toe, which, as has been stated, is caused as a rule by inward rotation of the entire limb rather than by a deformity of the toe or foot This rotation of the limb may be caused also by bow legs in which there is an accompanying inward twist of the tibiæ and occasionally it may be induced by a restriction of the range of outward rotation at the hip joints.

As a rule, however, pigeon toe is a compensatory attitude symptomatic either of weak feet or of knock knees, and it is therefore far more often a secondary than a primary attitude. The proper position of the

feet in walking, at least in childhood, is one of parallelism. In fact the exaggerated outward rotation of the feet which is so commonly seen, is more abnormal than a slight degree of in-toeing. As the latter attitude, from the conventional standpoint, passes for deformity it usually attracts the mother's attention before the weakness, of which it is so often a symptom.

Treatment.—The rational treatment must be directed to the cause of the peculiar attitude, viz., the bow leg, the knock knee, or the weak foot. In many instances the in-toeing habit remains for a time, after the removal of its cause, and systematic training in walking with the feet rotated outward may be necessary to overcome it.

If there be actual limitation of the range of outward rotation at the hip joints, as is sometimes the case, this must be overcome by systematic stretching.

In the absence of knock knee or weakness of the arch the tendency to in-toeing may be lessened by making the sole of the shoe somewhat thicker on the outer border.

In the more exaggerated types, the use of elastic tapes attached to the front and outer margin of the soles of the shoe, passing about the back of the leg from without inward over the front of the thigh and across the buttock, to be attached to the middle of the waist band, is an efficient treatment.

IX. Hammer Toe.—Hammer toe is a persistent flexion of a toe, usually of the second. In well-marked cases the first phalanx is dorsiflexed, the second plantar-flexed, and the third may be flexed and extended. The toe is usually compressed between its fellows, while its extremity, lying on a lower level, is flattened out against the sole of the shoe into a club or hammer shape. On the dorsal surface of the flexed joint which is subjected to pressure from above there is usually a sensitive corn or callus. The discomfort of the hammer toe is caused by the pressure of the shoe upon the corn above and upon the hypertrophied extremity below, of which the nail is not infrequently ingrown.

Etiology.—Hammer toe may be congenital, but in the great majority of cases it is an acquired deformity caused by narrow and short shoes. The second toe is more often involved because it is the longest and is subjected to greatest lateral pressure also. In cases of long standing all the tissues are shortened on the plantar or short surface, the most resistant contraction being in the ligaments of the first phalangeal joint.

Treatment.—Congenital hammer toe may be corrected in infancy by manipulation and by retention with a strip of adhesive plaster. The slight degrees of hammer toe in older subjects may be treated in a similar manner by methodical stretching and splinting with some light material such as celluloid. In such cases a digitated stocking is of advantage. In all cases a wide, capacious shoe which exerts no pressure whatever, is the first essential.

Confirmed hammer toe may be treated by division of the resistant parts, particularly of the ligaments of the first interphalangeal joint, and by correction followed by retention for a time with a digital splint of elastic material or a leather inner sole. In most instances, however, patients demand treatment for the relief of the discomfort caused by vertical pressure upon the flexed toe, rather than for the absolute restoration of symmetry. For this class the most efficient procedure is resection of the prominent joint, sufficient bone being cut away from the adjoining phalanges to remove the projection completely. By such a procedure permanent relief may be secured.

X. Overlapping Toes.—Irregularity in the line of the toes is sometimes observed in infancy; for example, a congenital hammer toe may be present or the little toe may be set upon a higher level than its fellows.

The irregularities may be treated by methodical manipulation and by retention of the distorted member by straps of adhesive plaster passed above and beneath it, fixing it to its fellows. Irregularities of this character in older subjects are almost always caused by improper foot wear, with the exception of distortions caused by rheumatism or by lesions of the nervous system, and the like. In this class, the use of a proper shoe will usually relieve the symptoms.

XI. Achillobursitis. (Achillodynia.)—In 1893 Albert (*Wien. med. Presse*, January 8, 1893) suggested the title Achillodynia to characterize a group of symptoms caused, in most instances, by irritation or inflammation of the bursa lying between the tendo Achillis and the posterior surface of the os calcis.

Etiology.—In certain cases the bursitis may be caused directly by pressure, injury, or overstrain, weak foot being a predisposing factor, but in many instances rheumatism, gout, gonorrhea, and the like, appear to be predisposing or exciting causes of this, as of similar affections of bursæ and tendon sheaths elsewhere. Concretions within the bursa or exostoses beneath it may be mentioned as possible causes, or complications.

Pathology.—In chronic cases the bursa is thickened and enlarged and the lining membrane is fringed and reduplicated. The contents may be serous or semisolid and concretions may be present. Suppuration may occur within the sac or it may be the seat of syphilitic or tuberculous disease. The periosteum in the neighborhood is usually thickened, and the underlying bone may be congested and softened.

Symptoms.—In typical cases there is sensitiveness to pressure over the back of the heel, and pain or discomfort exaggerated by functional use, particularly by motions and attitudes that increase the strain upon the tendon. The pain may radiate up the leg or it may be referred to the bottom of the heel. Patients often complain also of a sensation of laxity and insecurity in the subastragaloid articulation. In a large proportion of the cases the symptoms of the weak foot accompany or follow those of achillodynia. In the latter instance this is explained doubtless by the fact that the loss of the leverage function of the calf muscle induces an awkward gait with a strong inclination toward pronation of the foot, an attitude that throws an increased strain upon its inner border and upon the longitudinal arch. In cases of long standing there is marked atrophy of the calf due to disuse of function and in many instances a broadening of the posterior part of the heel caused by the infiltration or irritation of the periosteum about the insertion of the tendon. The enlarged bursa is usually demonstrable on inspection and palpation. The affection may be unilateral or bilateral, the latter being more common in chronic cases. As a rule the symptoms begin in one foot, the second becoming involved after an interval of several months.

When the symptoms have persisted for any length of time, there appears to be little tendency toward spontaneous recovery, a fact that is explained by difficulty in securing relief from pressure and strain in this situation.

Treatment.—In acute cases, particularly those that have followed injury, the treatment should be functional rest combined with the application of heat or cold, as may be indicated. When the immediate symptoms have subsided the part may be supported by adhesive plaster so arranged as to relieve the strain upon the sensitive part. A long band of plaster about two and a half inches wide is closely applied to the sole of the foot and calf of the leg, reaching from the toes nearly to the knee, with the foot in slight plantar flexion. This is supported by additional straps about the fore foot and leg, the ankle and heel being completely covered with narrow strips; a bandage is then applied. By this means the direct pull of the muscle on the sensitive part is checked and

compression is exerted upon the bursa. The dressing should be renewed when its efficiency is lessened.

If more complete fixation is indicated by the symptoms a light plaster bandage may be applied to hold the foot at a right angle with the leg and slightly adducted. The patient can then use the foot without discomfort. In many instances the application of the cautery seems to hasten the absorption of the effusion. If relief from function is necessary for any length of time, as in the chronic cases, it is well to apply a leg brace to the shoe with a joint at the ankle so arranged as to prevent dorsal flexion beyond a right angle. As patients are usually sensitive to direct jar, a rubber heel should be employed, and an increased height of the heel sufficient to throw the weight forward upon the front of the foot usually lessens the discomfort.

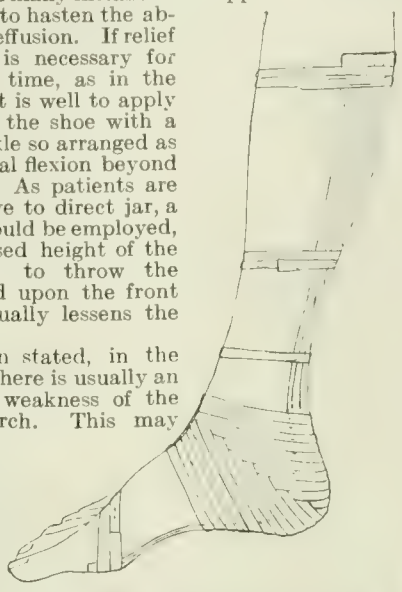


Fig. 2446.—The Manner of Applying Adhesive Plaster.

As has been stated, in the chronic cases there is usually an accompanying weakness of the longitudinal arch. This may require the application of a support and further treatment as described in the section on the weak foot.

Operative Treatment.—In persistent cases, particularly those in which the bursa is palpable and in which the adjoining tissues of the os calcis are infiltrated the removal of the bursa is indicated. This is accomplished by an incision beside the insertion of the tendon where the bursa is most prominent. Irregularities of the underlying bone should be removed at the same time. The wound is then closed and a plaster bandage is applied. This should be worn until the patient can walk without discomfort. Support may or may not be required in the after-treatment. Operative intervention is of course indicated when suppuration of the sac is present or when it is the seat of primary or secondary tuberculous disease. As has been stated, the local disability may be induced or prolonged by systemic disease. In such instances appropriate remedies should be employed.

XII. Achillobursitis Posterior.—A small sensitive bursa over the insertion of the tendon, between it and the skin, sometimes causes symptoms resembling those of the preceding affection. This bursa is usually caused by the pressure of the shoe, and it may be relieved by removing the exciting cause and by strapping with adhesive plaster.

Bursæ or sensitive points elsewhere on the heel are to be treated in a similar manner. Irregular projections on the bone may require removal.

XIII. Strain of the Tendo Achillis.—Pain on use of the foot referred to the tendo Achillis may follow strain or overuse, the symptoms may resemble those of Achillobursitis, but the sensitive point is often localized at the middle of the tendon or at the junction with the muscular substance. Apparently there is, in these cases, an irritation within the fibrous sheath of the tendon or injury to the muscular fibers.

The treatment is functional rest. As a rule the application of the adhesive-plaster strapping, as described in the treatment of Achillobursitis, is effective.

XIV. Painful Heel, Calcaneobursitis.—Pain and sensitiveness to pressure referred to the bottom of the heel are common symptoms of the contracted or hollow foot, in which there is abnormal pressure on the anterior and posterior pillars of the arch. It may be in normal feet a symptom of overuse, as when the tissues beneath the heel become sensitive after long standing or walking, and it is a common symptom of the weak foot of which the so-called heel walk is characteristic. Pain and sensitiveness may be caused directly by gonorrheal infection. This is most often at the attachment of the flexor brevis digitorum of the os calcis and it may lead to the formation of exostosis at this point. It must be born in mind however that exostosis in this region are by no means uncommon in apparently normal feet and that they may cause discomfort only because the arch is depressed.

In rare instances the point of tenderness is distinctly localized and is due to a small inflamed bursa lying over the periosteum of the inner tuberosity of the os calcis.

Treatment.—This must be directed to the condition of which the pain is a symptom. Effective treatment of gonorrhea or similar causes being the first consideration. The treatment of the weak foot and of the contracted foot is described elsewhere. If the sensitiveness is due to overuse or to abnormal pressure, the use of a rubber heel combined with frequent change from the passive attitude, in which the weight is supported entirely on the sensitive part, may relieve the symptoms. In many instances the use of an arched foot plate, to distribute the pressure along the entire sole, is of service.

Painful bursæ, inflammatory tissue, and exostoses, that cause persistent sensitiveness in spite of treatment, should be removed by a direct longitudinal incision just in front of the bearing surface of the heel.

Royal Whitman.

Foot, Distortions of the.—Talipes.—In the preceding article the disabilities of the foot, of which the discomfort is of greater importance than the deformity, have been described. One may now consider those of congenital and acquired origin of which deformity is the most noticeable feature. A distortion of the foot of this class is simply an abnormal retention of a normal attitude, or what is an exaggeration of a normal attitude. In other words the centers of motion, at which the foot is deformed, are the centers of normal motion, and the different distortions may be simulated by a normal subject. If the foot has been fixed in a certain attitude during fetal life, or if it has been used for any length of time in the abnormal position, the deformity becomes exaggerated beyond the possibility of imitation, and secondary variations in its shape, size, and nutrition follow.

The deformities of the foot are grouped under the generic name talipes, derived from talus (ankle) and pes (foot), signifying a form of deformity in which the patient walks upon his ankles. Talipes was therefore originally synonymous with the popular term club foot, but at the present time it is used as a prefix to the descriptive titles of the different distortions, while club foot is usually applied only to the most common of the deformities, equinovarus, in which the distorted foot is club-like in form.

Varieties.—There are four *simple* varieties of the distorted foot or talipes:

1. *Talipes Equinus*, the extended or plantar-flexed foot. In well-marked cases the patient walks upon the heads of the metatarsal bones, an attitude that suggested the name equinus (horse-like).

2. *Talipes Calcaneus*, the dorsiflexed foot in which the heel is prominent, and which alone bears the weight in walking; hence, calcaneus from calcaneum, the heel bone.

In these forms the center of distortion is at the ankle-joint. Under the terms equinus and calcaneus are included not only the cases of marked deformity, but also those in which the range of dorsal or plantar flexion is sufficiently limited to disturb the function of the foot.

3. *Talipes Varus*, the inverted foot. In this deformity the foot is turned in or adducted, and combined with the inward twist, which exaggerates the normal curve of the inner border, there is always a certain degree of supination, or inversion; that is, the inner border of the sole is elevated and the outer border is depressed, so that the weight falls to the outer side of the center of the foot.

4. *Talipes Valgus*, the everted foot. This deformity is the reverse of varus. The foot is abducted, that is the foot is twisted outward at the center and everted, so that in use the weight falls on the inner border.

In these forms of lateral deformity the centers of distortion are at the mediotarsal and subastragaloid joints.

The simple deformities in which the foot is persistently extended or flexed, or twisted in or out, are comparatively uncommon.

Compound Deformities.—As a rule, the deformities are combined in varying degree; thus, the over-extended or the overflexed foot is usually twisted inward or outward, making four varieties of compound deformity. 1. *Talipes equinovarus*—downward and inward. 2. *Talipes equinovalgus*—downward and outward. 3. *Talipes calcaneovarus*—upward and inward. 4. *Talipes calcaneovalgus*—upward and outward.

In the simple and compound varieties of talipes the arch of the foot may be increased or diminished in depth. It is, for example, usually increased in calcaneus and equinus, and it is usually diminished in valgus; but this secondary or subordinate deformity is not recognized in the ordinary classification. If the arch of the foot is exaggerated, the condition is sometimes called *talipes cavus;* if it is lessened or lost, *talipes planus.* These slight degrees of distortion, in which the functional disability is more important than the deformity, are rarely classed as forms of talipes. Simple cavus, the hollow or contracted foot, and planus, one of the forms of the common weak or flat foot, have been described already.

Etiology.—From the remedial standpoint, the cause of the deformity is of far greater importance than its form. Thus the distortions of the foot fall primarily into two groups: 1. *The congenital form*, in which the foot has become deformed in process of formation. 2. *The acquired form*, in which the foot, perfect at birth, has at a later time become distorted.

Congenital talipes is simply a twisted foot, of which the component parts, although malformed to a greater or lesser degree, are capable of regaining perfect form and function. This is practically true of the great majority of cases, although there are exceptional instances in which congenital deformity is complicated by defective formation of the foot or leg, or in which the deformity is caused by, or at least accompanied by, paralysis, as, for example, in certain forms of spina bifida or other congenital defect or disease of the nervous apparatus.

Acquired talipes is almost always a consequence of paralysis of spinal origin (anterior poliomyelitis) in early childhood. Certain muscles or groups of muscles being paralyzed, the muscular force is unbalanced and the foot becomes distorted by the action of the unopposed muscles, and by the influence of gravity. This distortion is confirmed and increased by the accommodative changes that accompany functional use and growth in the abnormal attitude.

Far less often acquired talipes is the result of paralysis of cerebral origin, of other forms of spinal disease, of local paralysis following neuritis or injury to a nerve trunk. It may be caused by scar contraction, as after a severe burn, or by direct injury to the bones, or by disease that may interfere with subsequent growth. Such are, however, relatively uncommon causes, and the statement holds good that congenital talipes is a simple distortion capable of perfect cure, while acquired talipes is a deformity usually secondary to disease of the spinal cord. It is therefore capable only of rectification, not of perfect cure, unless recovery from the original disease, of which it is a result, has taken place.

Congenital Talipes.—*Etiology*—The etiology of congenital talipes as of other congenital deformities is conjectural. In some instances the influence of inheritance is apparent, and again two or more children with club foot may be born of the same mother, but, as a rule, there is nothing in the family or personal history that can in any manner explain the deformity. The most reasonable explanation applied to the majority of cases is that the foot has from some cause remained for a longer or shorter time in a constrained or fixed position, and has thus grown into deformity.

It has been claimed by Eschricht, and by Berg (Berg, *Archives of Medicine*, New York, December 1, 1882) that at about the third month of intrauterine life the thighs of the embryo are abducted, flexed, and rotated outward, the legs are crossed, and the feet are plantar-flexed and adducted so that the inner surfaces of the thighs, the tibial borders of the legs, and the plantar surfaces of the feet are held in close apposition to the abdomen and to the pelvis of the fetus. Later there is an inward rotation of the legs so that the feet are turned gradually outward until the soles are brought into contact with the uterine wall, the feet then being in the attitude of abduction and dorsal flexion. According to this theory there is a regular succession of attitudes during intrauterine life. If the inward rotation of the lower extremity is prevented, or if it is incomplete, the foot remaining in the original position becomes deformed. Thus, equinovarus, being the normal attitude of the early and middle period of intrauterine life, is the most common and the most intractable of the congenital deformities. If the constraint or pressure is not exerted until a later period, after rotation has taken place, when the foot has attained or nearly attained its normal size and shape, it will then induce the less common and comparatively slight grades of deformity such as calcaneus or valgus.

This theory which seems interesting and reasonable, appears to rest on an insecure basis. Bessel Hagen states that in embryos of thirty millimeters in length, the foot is in extreme plantar flexion; in those of ninety to one hundred millimeters, the foot is at a right angle to the leg; and from this size to that at full term, the foot may be found in any position—abducted, adducted, or dorsiflexed. He states also that supination is not the usual attitude at an early period, but is more common near the termination of intrauterine life, and that when it is present it is more often combined with dorsiflexion. In other words, there is no time when the foot regularly and normally assumes the attitude of club foot, from which it is changed by the rotation of the legs. Scudder (*Boston Medical and Surgical Journal*, October 27, 1887), after similar investigations, arrived at practically the same conclusions. He states that there is no necessary relation between the age, the rotation of the legs, and the position of the feet.

It would appear, however, that there is during the process of development an alternation of attitudes and postures. If the feet for any reason are fixed in one position during this period of rapid growth, distortion must follow; if the constraint is slight, and if its influence is exerted at a late period, the deformity will be slight; if it occurs at an early period, the deformity will be more resistant.

One of the causes of constraint, and thus of ulti-

mate deformity, appears to be the interlocking of the feet. Many museum specimens show this, and in some of the cases of talipes seen during the first weeks of life, the feet may be replaced in the attitude in which they had been fixed before birth. Intrauterine pressure, although not necessarily direct pressure, undoubtedly has an influence in aggravating the deformity. The effect of pressure is not infrequently shown in atrophic areas of skin, and bursæ even are sometimes found over prominent bones. Entanglement in the umbilical cord, the direct pressure of extra- or intrauterine tumors, and the like, may be mentioned also as possible causes of restraint or fixation of the foot that induces deformity. Further evidence of restraint of normal movements and of

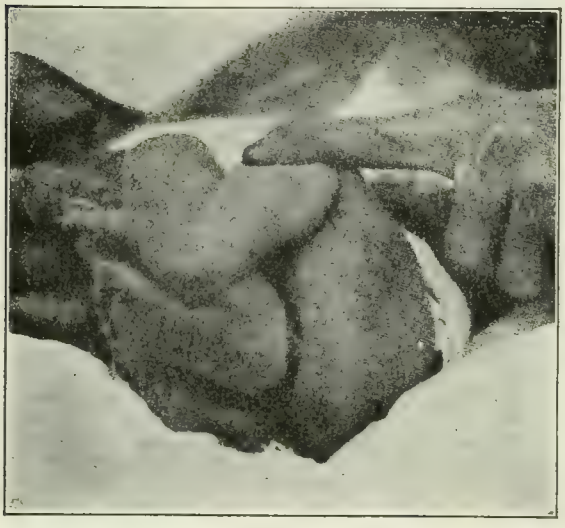


Fig. 2447.—Congenital Talipes Illustrating the Attitude of the Limbs at Birth.

abnormal attitudes of the limbs is seen not infrequently in connection with club foot. For example, there may be hyperextension or fixed flexion of the knees, and in cases of extreme deformity the foot is often smaller than normal or otherwise asymmetrical. In certain instances the distorted foot may be imperfect in structure; toes may be absent ("spontaneous amputation"), or constricting bands about the leg or foot may be present. Such abnormalities are usually ascribed to amniotic adhesions. Talipes may be combined with evidences of impaired or arrested development, with harelip, exstrophy of the bladder, spina bifida, absence of patellæ, or with other deformities, such as club hand and wry neck. Or there may be evidence of intrauterine disease, as shown by ankylosis of joints or by so-called fetal rickets. Finally, deformities of the foot may be complicated by absence of bones of the foot or of the leg, indicating original defects in the germ itself. This latter group, which includes the complications of club foot and imperfection of structure, is comparatively small. As has been stated, congenital club foot, in the great majority of cases, is a simple deformity capable of perfect cure.

The relative frequency of the congenital and acquired forms of talipes has given rise to much discussion in the past, and statistics on this point are at considerable variance with one another. This may be explained by the fact that acquired paralytic talipes is, as a rule, a preventable deformity. At the present time the extreme degrees of acquired talipes are comparatively infrequent and the deformity is usually of a much slighter grade than the corresponding form of congenital distortion.

	Males.	Females.	Total.
Sex of congenital talipes	1355	748	2103
Percentage	64 4	35.6	
Sex of acquired talipes	1416	1199	2615
Percentage	54.1	45.9	

Congenital talipes is much more common among males than among females. All statistics are in accord upon this point. Acquired talipes is more equally divided between the sexes.

	Right.	Left.	Both.	Total.
Foot affected in congenital talipes	643	552	908	2103
Percentage	30.4	26.1	43.5	

Unilateral 1195 = 57.5 per cent. Bilateral 918 = 43.5 per cent.

	Right.	Left.	Both.	Total.
Foot affected in acquired talipes	1126	1102	387	2615
Percentage	43	42.1	14.9	

Unilateral 2228 = 85.1 per cent. Bilateral 387 = 14.9 per cent.

In congenital talipes the deformity is nearly as often of both as of one foot, while in the acquired form unilateral deformity is far more common. In each variety the right foot appears to be more often effected than the left.

The Relative Frequency of the Different Forms of Congenital Talipes.

	Cases.	Percentage.
Equinovarus	1629	77 4
Valgus	144	6 8
Varus	89	4.2
Calcaneovalgus	87	4 1
Equinus	49	2.3
Calcaneus	47	2.2
Equinovalgus	35	1.6
Calcaneovarus	10	.....
Cavus	5	.....
Valgocavus	1	...
Equinocavus	1	..
Different deformity in each foot	54	.

Relative Frequency of the Different Forms of Acquired Talipes Together with the Etiology.

	Spinal.	Cerebral.					
	Anterior poliomyelitis	Hemiplegia.	Paraplegia	Other forms of paralysis.	Traumatic.	Total.	Per cent.
Equinovarus	610	59	41	18	56	784	30.
Equinus	469	102	50	14	43	678	25.9
Calcaneus	318	7	3	9	20	352	13.4
Valgus	205	6	10	1	37	259	9.9
Equinovalgus	163	1	5	1	7	177	6 7
Calcaneovalgus	123	1	1	1	15	141	5.4
Varus	68	8	3	1	10	90	3.1
Calcaneovarus	13	0	1	1	0	15	0.5
Equinocavus	38	0	0	0	2	40	1.5
Calcaneovarus	15	0	0	1	1	17	0.6
Cavus	48	1	1	0	4	54	0.2
Varocavus	2	1	1	0	0	4	
Deformity different on each side.	2067	186	116	47	195	2611	

Anterior poliomyelitis. 2067 = 79.9 per cent.
Cerebral. 302 = 11.5 per cent.
Traumatic. 195 = 7 per cent.

Comparative Frequency of the Different Forms of Talipes, Congenital and Acquired

	Congenital	Acquired.
Equinovarus	77.4 per cent.	32.5 per cent.
Valgus	6.8 per cent.	9.7 per cent.
Varus	4.2 per cent.	2.7 per cent.
Calcaneovalgus	4.1 per cent.	4.4 per cent.
Equinus	2.3 per cent.	26.1 per cent.
Calcaneus	1.6 per cent.	12.6 per cent.

According to these statistics, in three-fourths of the congenital cases the deformity is equinovarus. Equinus and calcaneus, rare as congenital deformities, comprise one-third of the acquired forms.

Occasionally the deformity of each foot is different, far more often in the acquired than in the congenital form. In 7 of the 18 congenital cases the deformity was equinovarus on one side, calcaneus on the other; in 3 equinovarus and calcaneovalgus, and in 3 simple varus and valgus. The 50 cases of acquired talipes represented every combination of deformity.

In 31, or 4 per cent., of 735 cases of congenital talipes, the distortion was combined with other congenital defects or deformities, viz., in 12 cases with double club hands; in 6 cases with defective development of the hands, webbed fingers, and the like; in 7 cases with spina bifida; in 3 cases with absence of one or more bones of the leg; in 1 case with torticollis; in 1 case with harelip; in 1 case with dislocation of the knee and ankylosis of an elbow; in 2 cases with general rigidity and deformity of the joints.

Anatomy.—Congenital talipes is, in the great majority of cases, the form in which the foot is twisted inward and downward, or in the more extreme cases, inward and upward, and in its club-like appearance justifying the popular name. The ordinary congenital club foot in early infancy is simply a foot held in an attitude of plantar flexion, adduction, and inversion. The dorsum of the foot looks forward and slightly outward and upward, the plantar surface is abnormally concave and looks backward, inward, and downward. In many cases the equinous element of the deformity, masked by the extreme inversion of

Fig. 2448.—Congenital Club Feet in Sisters, the Twelfth and Thirteenth Children; All the Others Normal.

the foot, does not appear until this has been corrected in part. The foot often seems somewhat smaller than normal, and the heel appears to be ill formed. Upon the outer dorsal surface the astragalus projects beneath the skin. The external malleolus is prominent, while the internal malleolus lies deep beneath the redundant tissue of the internal aspect of the foot.

The internal structure of the foot corresponds to the external contour; thus the relation of the bones to one another, and the shape of the individual bones even, are more or less altered as the deformity is more or less of an exaggeration of the attitudes that the normal foot is capable of assuming. These changes are most marked in the astragalus and os calcis. The astragalus is somewhat wedge-shaped from without inward; it is plantar-flexed so that a large part of its body protrudes from between the malleoli. Its neck is often somewhat longer than normal, and it is, as a rule, depressed and deflected inward. The os calcis is also in an attitude of plantar flexion; the external tuberosity is drawn upward to the vicinity of the

Fig. 2449.—Resistant Club Foot Showing the Secondary Knock Knees.

external malleolus, its anterior extremity looks downward and inward, and it is often twisted inward on its long axis corresponding to the deformity of the neck of the astragalus. Its external surface looks downward and forward, and it lies directly beneath the astragalus, instead of to its outer side as in the normal relation.

The scaphoid is drawn inward and upward, and articulates with the inner part of the deflected head of the astragalus, lying in close proximity to, and often articulating with, the internal malleolus. The cuboid is displaced upward and inward and lies to the inner side of the anterior extremity of the os calcis. The remaining bones are changed in position, but not materially in shape. In many instances the tibia is rotated inward upon the femur at the knee joint, and combined with this inward rotation there may be an inward twist of the tibia on its long axis.

The ligaments are altered to correspond to the changed relations of the bones. Those on the short side are more or less resistant according to the duration of the deformity. The muscles are normal as to their structure and their origin and insertion, but the direction of the tendons as they pass across the foot is changed. Those attached to the inverted side, the extensor and adductor group, are shortened and are relatively stronger than those on the outer side, which are lengthened and atrophied from disuse.

To sum up: all the component parts of the foot participate in the deformity. The most noticeable changes in the bones are in their position and relation to one another, but the astragalus, os calcis, and scaphoid are usually somewhat distorted.

The most resistant structures in the deformed foot are the plantar fascia and the ligaments that bind the scaphoid, the os calcis, and the internal malleolus to one another. The muscles that are most active in retaining and increasing the deformity are the tibialis anticus, the tibialis posticus, and the combined gastrocnemius and soleus.

The changes that have been outlined, which are comparatively slight and which may be easily rectified soon after birth, become more marked as the part develops. And when the child begins to walk, the weight of the body, combined with growth and functional use in the abnormal position, increases and fixes the deformity.

In the adolescent or adult type of club foot the deformity may be so extreme that the patient actually appears to walk on the outside of his ankles, as the term talipes implies. The feet turn directly inward, or even inward, upward, and backward, and the peculiar walk, by which interference of inverted feet is prevented, has given another name (reel foot) to the deformity.

Genu valgum is usually present in such cases. This deformity may be congenital, but it is oftener a secondary or accommodative distortion. The legs are shrunken from disuse. The foot itself is atrophied, and is much smaller than the normal. The changes in the bones are much more marked; only a small part of the articulating surface of the astragalus lies between the malleoli, and this posterior extremity is flattened out to the shape of a wedge. There is consequently an apparent backward displacement of the fibula.

All the bones of the foot are more or less atrophied, and the normal area of cartilage has, to a great extent, disappeared from the proper articular surfaces. In this advanced stage the foot serves practically as a simple rigid support.

In these extreme cases cure, in the sense of perfect functional recovery, is of course out of the question; but relief of the deformity, that is, replacement of the foot in the axis of the leg at a right angle to it and in the plantigrade attitude, is nearly always possible.

Symptoms.—The symptoms of congenital club foot are practically included in the description of the deformity. The functional disability is of course considerable, although some patients are surprisingly active and are able to walk long distances. Discomfort from club foot is due almost entirely to the corns or inflamed bursæ over the bony prominences, and its degree depends of course upon the use to which the foot is subjected.

Treatment.—Although congenital club foot is an eminently curable deformity, yet perfect and permanent cure requires minute attention to details during the active stage of treatment, supplemented by long-continued and careful supervision after the cure is supposed to be complete. No other deformity presents such a record of failures and incomplete cures; of relapses after apparent cure; of tedious and ineffective treatment by braces, often for many years, and of unnecessary and mutilating operations. Some of the failures may be explained by the neglect of the parents and by want of opportunity. A few are due to the unusual obstacles in the deformity itself, but by far the greater number must be accounted for by failure of the physician to apprehend the true nature of the deformity, or by his inexperience in the practical details of treatment.

Proper treatment implies suitable opportunity. Under such conditions the treatment of congenital club foot would be included in the first of the following sections:

The infantile club foot is, as has been stated, simply a twisted foot. It is true that there are slight changes in the bones, but the bones of an infant's foot are represented by yielding cartilage which will rapidly reform under changed conditions. The shortening of the muscles and ligaments may be overcome, and when the relation of the bones to one another is set right, the joints will become normal. The treatment of a club foot may then be divided into three stages:

1. The rectification of the external deformity.
2. The support of the foot in proper position during the process of transformation of its internal structure, and until the normal muscular power, unbalanced by the deformity, has been regained.
3. The period of supervision. This would include the treatment of possible complicating deformities of the knee, the laxity of ligaments, and the like, as well as the oversight of the functional use of the foot and the leg during the early years of life.

The First Stage of Treatment: Rectification of Deformity.—It should be stated at once that "rectification of deformity" does not mean apparent symmetry, a misapprehension to which the majority of failures in treatment may be ascribed. It means that when deformity is really rectified all contracted and resistant parts must have been so elongated that every passive motion and attitude possible for the normal foot is equally possible and as easily attained in that which was deformed. This is actual functional rectification, as contrasted with the simple straightening of deformity.

The most important part of the club-foot deformity is varus. The foot that is rolled over and twisted inward to the attitude of extreme adduction must be untwisted and forced into the attitude of extreme abduction or valgus, the so-called overcorrection. Until this is accomplished no attention whatever need be paid to the residual equinus. There are two reasons for dividing the procedure into two parts: first, in order that the attention of the surgeon may be concentrated on one and the most important part of the deformity; second, because by this preliminary untwisting the os calcis is brought into the upright position, into its proper relation to the astragalus, to the bones of the leg and to the tendo Achillis, so that the true degree of equinus may be appreciated.

Preliminary Manipulation.—For obvious reasons, the second week of life is usually as early as mechanical treatment can be undertaken. Until then, preliminary manipulation by the nurse, more particularly manual rectification of the deformity by gently drawing the foot toward abduction and retaining it in the improved position for a few minutes, as often as is possible, may be of service in overcoming its resistance. As a treatment by itself, however, simple manual rectification is tedious and ineffective, although partial cures have been attained by perseverance with this means alone.

Mechanical rectification is the treatment of choice and routine in infantile club foot. In this treatment two methods may be described: (1) by the plaster bandage; (2) by some form of simple splint.

The principle of the two is essentially the same. The foot is drawn toward an improved position and retained there by the plaster bandage, or it may be fixed to some form of metal splint or brace whose shape is gradually changed from week to week, as the resistance lessens.

Gradual Rectification of Deformity by Means of the Plaster Bandage.—In this treatment care should be taken to avoid undue pressure, irritation of the skin, or insecurity of the bandage. Shreds of cotton should be placed between the toes, and the outer aspect of the ankle where the skin is thrown into folds when the foot is streightened, should be smeared with vaseline. If the leg is fat so that the bandage is likely to be displaced a narrow strip of tadhesive plaster long enough to reach from the knee to a point a inch or

more below the heel is applied to the outter side of the leg. A thin layer of cotton is wound about the leg just below the knee, in order to protect the skin from the hard margin of the plaster bandage, and a similar strip is carried about tke toes. The foot is then drawn gently toward the abducted position, often as far as the axis of the leg at the first dressing, without causing discomfort. While it is held in this position a narrow flannel bandage is smoothly applied to the leg and foot, the band of adhesive plaster being drawn out between the folds about the ankle. A very light plaster bandage is then applied from the knee to the extremities of the toes, and into this bandage the projecting strip of adhesive plaster is incorporated, so that no displacement of the dressing is possible. The turns of both the plaster and the flannel bandage are made from within, downward and outward in order

Fig. 2450.—The First Application of the Plaster Bandage, Showing the Improved Position.

that the tension may aid in retaining the foot. When the plaster bandage, which during the hardening process has been constantly rubbed and manipulated so that it may fit the part perfectly, has become firm, a long stocking is drawn over it and is attached to the body clothing. At the end of a week the bandage is removed. The leg and foot are gently bathed with alcohol, thoroughly dried, powdered, and protected as before, and the bandage is again applied. At this second dressing the irritated adductor muscles, after the interval of complete rest, will be much less active and the contracted tissues will be less resistant, so that the foot may be easily turned somewhat outward, or beyond the line of the leg.

After four or five applications of the bandage at weekly intervals the foot, in ordinary cases, can be held without resistance in the attitude of extreme equinovalgus. The sole, which at first looked backward, inward, and upward, is now turned in the opposite direction, forward, outward, and downward, and the inner border of the foot, which was concave, is now convex. When the varus has been completely overcome, treatment is directed to the equnius. At the first application of the dressing one carries the foot upward (toward dorsal flexion), while it is still retained in the abducted position; but when the right-angled position has been attained, it is brought nearer to the axis of the leg. The pronation or eversion of the sole is retained, however, until correction is completed. In correcting the equinus, a certain degree of force is required, sufficient to cause some discomfort during the application of the plaster, but not sufficient to cause suffering afterward. The pressure is applied to the entire foot so that the posterior extremity of the os calcis may be drawn downward by actual lengthening of the tendo Achillis, and not, as is often the case, by an overcorrection of the forefoot, while the heel remains in its original position of plantar flexion. By the proper application of force the equinus is gradually overcome; the sharp indentation or fold at the insertion of the tendo Achillis is lessened, and the heel becomes more prominent.

The reduction of the equinus may be somewhat more difficult than that of the varus, but it should be entirely corrected in three or four months from the time of beginning the treatment.

As has been stated, correction of the deformity implies overcorrection; and it is well when this has been attained to hold the foot for several weeks, by means of the plaster bandage, in an attitude of extreme eversion and dorsal flexion (calcaneovalgus) in order to impress, as it were, the new position upon its structure.

This concludes the first stage of the treatment, the simple rectification of deformity.

Correction by the plaster bandage has the great advantage of placing the treatment entirely under the command of the surgeon. When properly applied, the support fits perfectly and holds the foot in the desired attitude without undue pressure.

The disadvantages of the treatment are almost entirely due to its improper application. For instance, the bandage, which should be of about the thickness of blotting paper, may be too heavy, or the padding may be so thick that it does not retain its position. Excoriations are usually due to carelessness in the application of the bandage or they result from a failure to remove it in proper season. The fear of compression, of atrophy of muscles, of stunting the growth of the foot, is groundless. At the end of the retention treatment the corrected foot is, as a rule, larger than one that has been untreated. The stunted foot is the result of non-treatment, or of ineffective treatment by braces or otherwise; not of the enforced rest necessitated by the methodical and rapid reduction of deformity.

It may be noted in this connection that the normal infant moves the foot in various directions in a more or less regular alternation of postures, while in club foot motion is in one direction only, that toward which the foot is turned. The muscles on the back and inner side of the leg, which are alone active, become relatively irritable and hypertrophied as compared with those on the front and outer side that are disused. Thus, muscular activity of the deformed foot is in reality harmful, because it increases deformity and still further disturbs the muscular balance. For this reason the temporary restraint of motion, necessary during the rectification of the deformity, may be considered rather of advantage than otherwise. When movement is again allowed and encouraged, it must be in the directions opposed to the attitudes of deformity, with the aim of so strengthening the weakened group of muscles at the expense of the stronger, that the balance of muscular power may be reëstablished.

Correction of deformity may be accomplished by holding the foot in an improved position by strips of adhesive plaster, or by the elastic traction of rubber bands attached to the leg and foot. As compared with the ease, rapidity, and certainty of correction by the plaster bandage, such methods are uncertain and ineffective and they will not therefore be described in detail.

The Rectification of Deformity by Splints and Braces.—Of mechanical supports there are many varieties. Complicated appliances should be avoided because they are unnecessary, and because they serve to distract attention from the prime object of treatment, the rapid and systematic correction of deformity.

Of the simpler braces, that used by Judson of New York is one of the best and will serve as a type to illustrate this form of treatment. The method of application may be described in Judson's own words:

"The apparatus which I have conveniently used to effect this reduction before the child learns to stand is a simple retentive brace which acts as a lever making pressure on the outer side of the foot and ankle, at *A*,

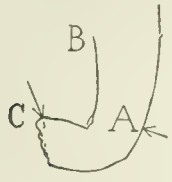


Fig. 2451.

Fig. 2452.

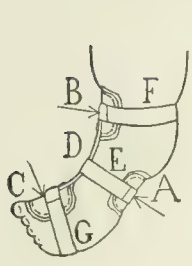


Fig. 2453.

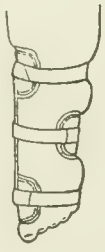


Fig. 2454.

Fig. 2455.

Fig. 2456.

Fig. 2457.

Fig. 2458.

in Figs. 2451 to 2453, inclusive, and counterpressure at two points, one on the inner side of the leg, at *B*, and the other at the inner border of the foot, at *C*. It is advisable to keep in mind that this simple instrument is a lever, because, if we know that we are using a lever with its three well-defined points of pressure, we can make the apparatus more efficient than if we view it, in a more general way, as an apparatus for giving a better shape to the foot.

"I use a little brace made of sheet brass, doing the work with a few simple tools. An advantage of doing the work one's self is that there is no room for doubt as to where the blame lies if the apparatus does not work well. Two curved discs, *B* and *C*, Figs. 2452 and 2453, are riveted to a shank, *D*, and thus is formed that part of the brace which applies the two points of counterpressure, while, on the other hand, the point of pressure is brought into action by a third disc, or shield, *A*, which is drawn tightly against the outer side of the foot and ankle, and held in place by a strip of adhesive plaster *E*, which includes the limb and the piece which connects the two discs, *B* and *C*. The discs are lined with two or three thicknesses of blanket, easily renewed, when necessary, with a needle and thread. These braces are so cheap and easily knocked together that it is nothing to apply new and larger ones, using heavier material for the shank as the child grows. In general, three sizes will be enough, the shanks being 12 gauge, $\frac{3}{8}$ in. wide; 14 gauge, $\frac{1}{2}$ in. wide; and 16 gauge, $\frac{5}{8}$ in. wide. The discs are conveniently made from 22 gauge, $1\frac{1}{4}$ in. wide. The rivets are copper belt-rivets, No. 13. A lip turned on the edge of the discs, with the flat pliers, gives stiffness to the thin brass, and protects the skin from the rough edge. If more easily obtained, tin discs, light bars of iron or steel, and ordinary iron rivets, would doubtless answer. (See Figs. 2452, 2457, and 2458.)

"The brace is applied with three strips of adhesive plaster. The upper and lower pieces, *F* and *G*, Fig. 2453, are simply to keep the apparatus in place, which they do effectively if ordinary gum plaster is used, while, by drawing the middle strip, *E*, tightly over the shield, and straightening the brace from time to time, the deformity is gradually and gently reduced. At each reapplication the brace is made a little straighter than the foot at that stage. This may readily be done by the hands, and then the adhesive strip is to be tightened over the shield till the shape of the foot agrees with that of the brace. After a few days, the brace is to be made still straighter and again reapplied, and made tight till another point of improvement is gained. The brace is applied very crooked at the beginning of treatment, as in Figs. 2452 and 2453, and is straightened from time to time, and a longer brace applied as the deformity is reduced and the patient grows. It should be removed every week or two weeks, and an interval of a few days allowed for freedom from the brace, when the mother is advised to manipulate the foot constantly, using as much force as she will in the direction of symmetry. Manipulating the foot during these intervals is of great importance, as cases have occurred in which varus and equinus have been entirely overcome by the mother's hand alone.

"By this simple and prosy treatment, carried out systematically and without haste, or violence, or pain, the foot, unless it is a frightful exception, may with certainty be changed from varus to valgus. At the same time the tendo Achillis is lengthened till the position of the foot is near the normal, or at right angles

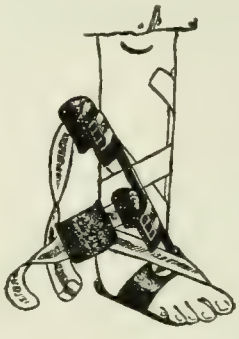


Fig. 2459.

Fig. 2460.

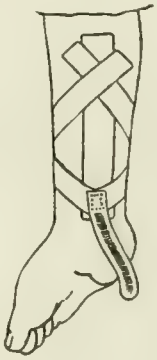


Fig. 2461.

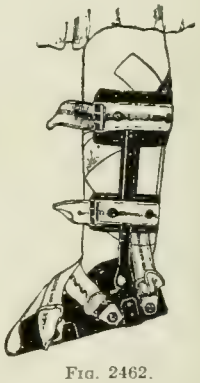


Fig. 2462.

Figs. 2459 to 2462.—The Taylor Club-foot Brace.

with the leg, as the result of manipulation and giving the brace from time to time a partly anteroposterior action. Figs. 2452 and 2453 show approximately the shape of the brace at the beginning of treatment, Fig.

2454 when the varus is reduced, and Fig. 2455 when valgus has taken the place of varus. The foot, in this latter stage, may not hold itself valgus, when left to itself, but with almost no force and with one finger it may be pushed into valgus."

When the varus deformity is reduced, the equinus is gradually corrected by carrying the splint behind the internal malleolus, and finally, if necessary, direct upward pressure may be obtained by lengthening the brace and applying it to the posterior aspect of the foot and leg. It may be noted that manipulation and stretching of the contracted parts when the brace is removed are of much importance in the correction of deformity by this or other means. Splints of wood, tin, felt, and the like may be employed, but they present no particular advantage over that which has been described.

Tenotomy.—The equinus has been spoken of as the secondary deformity, but its complete correction is sometimes more difficult than that of varus. The mechanical stretching of the contracted parts by means of the plaster-of-Paris bandage or the brace, is often accomplished with ease, but in more resistant cases time will be gained after the foot has been forced into the position of equinovalgus, by the division of the tendo Achillis, which is the most resistant of the shortened tissues. After division of the tendon it may be necessary to use considerable force to stretch the other contracted parts, and to push the foot up to the limit of normal dorsal flexion, which is the object of the operation. Occasionally the obstacle seems to be in the posterior ligament of the ankle, and it is sometimes of service to reinsert the knife and to divide this structure, in part at least, so that it will give way under manipulation. When the foot has been forced into the position of overcorrection, it is fixed in a plaster bandage which is allowed to remain for several weeks, until the interval between the separated ends of the tendon is filled in with the new tissue.

In many instances the leg is rotated inward upon the thigh, an attitude that is accompanied by accommodative changes in the ligaments of the knee-joint. During the rectification of the club foot, this secondary distortion may be corrected, in part at least, by forcible manual rotation of the leg outward on the thigh, several times daily.

The management of the first stage of the treatment of infantile club foot is then—manipulation by the nurse or parents from birth until systematic rectification can be begun, mechanical correction, first of the varus and then of the equinus deformity, terminating with a period of retention in the over-corrected position (calcaneovalgus). Division of tendons, other than the tendo Achillis, is not often necessary. The time required for the first stage of treatment, or overcorrection of deformity, should not under favorable conditions exceed three months.

The rapid and complete correction of deformity in the manner described, begun as early as possible and accomplished as quickly as possible, cannot be too strongly urged. In the first months of life the tissues are not resistant, the bones are in large part cartilaginous, and when the foot in its external appearance is rectified, the rapid growth in the first months of life will change the internal structure to conform to the normal conditions. The fear of atrophy, compression, or other harm from the temporary fixation necessary during rectification is groundless, and in fact exercise, so-called, except in the direction opposed to deformity, is harmful rather than beneficial.

The Second Stage of Treatment: Support and Restoration of Function.—When the deformed foot has been corrected, in the sense that all normal motions are unhampered, the first and most difficult part of the treatment will have been completed, and in some instances a practical cure is assured. Such a result is unusual, however, for although the foot may be normal in appearance, its muscular balance has not been restored. This is shown by the fact that there is little power in the dorsal flexors and abductors to draw the foot upward and outward. For this reason, the foot must be supported in proper position until the slack of the lengthened tissues has been taken up by development in the normal attitude, otherwise the deformity must recur. Practically, support is always necessary until the child has begun to walk.

The Retention Brace.—The form of retention brace will vary somewhat according to the indications of the

Fig. 2463. The Adhesive Plaster Support as used after Correction of the Deformity. (From Whitman's Orthopedic Surgery.)

individual case, the one essential being that the foot shall be supported in an attitude of dorsal flexion and abduction until the transformation of deformity is completed. In the treatment of infants a light brace of tin or aluminum may be held in position by adhesive plaster. One of the best supports is the Taylor brace, the invention of Dr. C. F. Taylor of New York. This consists essentially of a light upright that extends along the inner side of the leg to the knee, and a thin steel foot-plate of the exact size of the sole, with an upright flange on the inner side rising to a point just above the dorsal surface of the foot, against which the foot is closely pressed so that recurrence of the varus deformity is prevented. The joint at the ankle is provided with a catch that prevents plantar flexion, but allows dorsal flexion (Figs. 2459, 2460, 2461, and 2462). By bending the upright and the sole plate the foot may be held in slight abduction. The apparatus is applied with straps as illustrated, and if necessary its position is further fixed by a band of adhesive plaster applied on the inner side of the leg to hold the heel firmly against the foot-plate. The foot is thus held constantly at a right angle to the leg, or better, in the early stage of treatment, in an attitude of dorsal flexion and valgus. Occasionally, after complete rectification of the deformity, the foot still turns in. In most instances this is due to an inward rotation of the tibia on the femur at the knee-joint, but in some cases it is caused by a spiral twist of the tibia itself. In order to correct this secondary

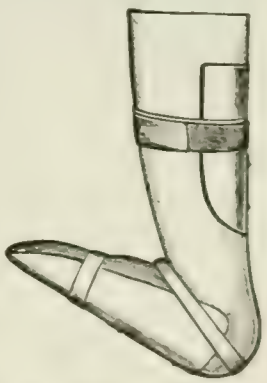


Fig. 2464. A Retention Brace used in Infancy. (From Whitman's Orthopedic Surgery.)

deformity the upright of the brace is carried beneath the leg, provided with a joint at the knee, and extended up the outer side of the thigh. At the hip it is attached by a free joint to a padded pelvic band of light steel. The band holds the upright in the proper relation to the thigh; thus, by twisting the part below the knee the foot can be rotated outward to the desired degree. In less marked cases, the retention bands used for pigeon toe may be employed. (See Pigeon Toe in article on *Foot, Disabilities of the.*)

Fig. 2465.—Club-foot Braces, to Correct Inward Rotation.

Methodical Manual Correction.—Several times during the day the brace should be removed in order that the foot may be thoroughly massaged and forcibly abducted, that is, twisted outward at the mediotarsal joint so that the inner border is made convex, and then to the extreme limit of dorsal flexion and abduction. If the leg is rotated inward, it is forcibly turned outward on the femur. Even if the tibia is actually twisted on its long axis, the influence of the brace and forcible manipulation will usually correct the deformity. If not, an osteotomy of the tibia may be required at a later period; this, however, is not often necessary. Active contraction of the weak muscles may be induced by tickling the sole of the foot or by the use of electricity; and finally, the entire limb should be thoroughly massaged before the brace is reapplied.

When the ability to dorsiflex and abduct the foot has been regained, the brace may be removed for a part of the day; later it is used only at night, and finally it may be discarded if the child walks normally. But it is best to continue the daily manipulation, more particularly the systematic stretching or overcorrection of the foot, for a long time. Thus one may check the tendency toward deformity of which the first sign in always a slight limitation of the range of dorsal flexion and abduction.

In many instances the deformity may have been so thoroughly overcorrected by the plaster-of-Paris bandage or by the brace, and the after-treatment of massage and stretching may have been so efficiently applied by the nurse or parent that no support is required after the child begins to walk. On the other hand, the inclination toward deformity may be so marked that it may be necessary to hold the foot in slight abduction and valgus for a year or longer.

In other cases, the use of a light brace to hold the foot in the overcorrected position during the night is alone required. These are points to be decided by the circumstances of each case. The period of observation and supervision is included in the final stage of the treatment.

Third Stage of Treatment: Supervision.—During this period the attitudes of the limb and foot of the child in walking must be carefully watched and one should observe the signs of wear on the sole of the shoe. If it shows greater wear on the outer side than is usual, it is an indication that the weight does not fall on the center of the foot and that there is therefore a tendency toward deformity. This must be counteracted by making the sole thicker on the outer border, or somewhat wedge-shaped, so that the weight may be deflected toward the inner side.

This third period of treatment, or rather of oversight of the functional use of the foot, must be continued indefinitely. In fact, it is the quality of this final supervision that decides in most instances whether the ultimate outcome is to be what is called a satisfactory result, or a perfect cure.

The Treatment of Neglected Club Foot.—The treatment of club foot, under what may be called the proper conditions, as outlined in the preceding pages, applies practically to all cases before the completion of the first year of life, and mechanical rectification may be successfully employed in cases far beyond this limit of age. As a rule, however, when the patient has walked for any length of time, the resistance of the tissues has increased to such an extent that more rapid and effective treatment is indicated. The investigations of Wolff have shown that the internal structure of the bones corresponds to their external contour, and that the structure and contour are adaptations to functional use. This internal structure is not, however, permanent, but is readily transformed to conform to changes in form or function. If then the external contour of the club foot were suddenly reversed, and if use of the foot were permitted in this new attitude, a transformation of the internal structure of the bones and at the same time of their shape would begin at once. This would continue until both structure and shape had become adapted to habitual function. It is upon this natural power of transformation that one depends for the final and complete change of the distorted bones to the normal; and what is true of a resistant structure like bone is equally true of the other constituents of the deformed foot.

Age as Influencing Treatment.—There is then this very essential difference between the indications for treatment in infancy and in childhood. In the first instance the foot has no essential function. In the walking child, however, the weight of the body and habitual use tend to confirm and to increase the deformity. As a general principle of treatment, therefore, walking should not be permitted until the weight of the body may aid rather than retard the correction of deformity. This is another point in favor of rapid, as opposed to gradual, correction of deformity.

The Rapid Correction of Deformity.—The principles on which operative treatment is conducted are the same as those which govern mechanical treatment. Thus the deformed foot must be overcorrected, and it must be held in the overcorrected position, until the

immediate tendency toward deformity has been overcome. It must then be supported until the foot has become adapted to its new position and until the balance of muscular power has been regained. No surgical operation, however radical, can be, in childhood at least, curative by itself alone. Operative procedures are undertaken simply for the purpose of making the primary overcorrection possible, and that operation by which this object can be accomplished, with the least interference with the structure of the foot, should be selected. Such an operation is what may be called forcible manual correction, first described by Delore of Lyons.

Forcible Manual Correction.—The patient having been anesthetized, one first attempts to correct the sharp inward twist at the mediotarsal joint. Supposing the right foot to be deformed, one grasps the heel with the right hand in such a manner that the projection or muscular part of the palm lies on the outer aspect of the foot, against the most prominent part of its outer border, which is at the junction of the os calcis and cuboid bones. This hand serves as a fulcrum, over which the inverted foot may be bent. The

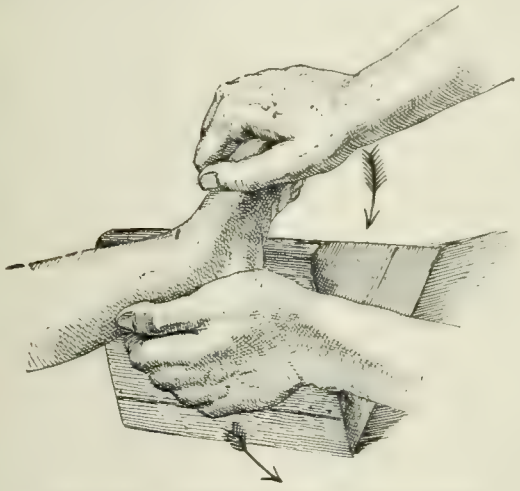


Fig. 2466.—Reduction of Varus. (After Lorenz.)

forefoot is then grasped firmly by the left hand and one begins a series of outward twists over the fulcrum of the opposing palm, gently at first with alternate relaxation of pressure, but with gradually increasing force as the resistant tissues stretch under the tension.

If greater force is required, a triangular block of wood, well padded, may be used as the fulcrum (Fig. 2466), one hand pressing on the heel and the other on the forefoot; but there is a great advantage in using nothing but the hands, because one feels sure that no injurious force is likely to be exerted. Under this steady manipulation, the foot soon loses its rigidity and its elastic recoil toward deformity; it becomes so limp that with two fingers one can not only hold the sole straight, but can push it or bend it outward. Thus the first stage of the methodical correction has been accomplished.

One then turns his attention to the inversion which makes the outer border of the foot lower than the inner border. The leg is grasped firmly near the ankle with the left hand, and with the right the foot is forcibly twisted in a direction downward, outward, and upward, over and over again, with steadily increasing force as the tissues slowly yield, until it may be forced into a position of extreme abduction, so that the sole may be made to look outward and downward—the reverse of the former attitude.

One next stretches the contracted plantar fascia and reduces the cavus, which is usually present, by forcing the forefoot toward dorsiflexion, against the resistance of the contracted tendo Achillis, until the sole is made perfectly flat (Fig. 2467). Finally, the fourth, and often the most difficult part of the rectification, that of forcing the displaced astragalus into its proper posi-

Fig. 2467.—Reduction of Cavus. (After Lorenz.)

tion between the malleoli, is attempted. To accomplish this, the tendo Achillis is first divided subcutaneously, and if necessary the posterior ligament of the ankle is also divided at the same time. The patient is then turned upon his face so that with the knee resting on the table the leg is held upright. This allows one to hook the fingers about the extremity of the os calcis while the hand and arm, lying along the sole of the foot, may be used as a lever to force it toward dorsal flexion as the os calcis is drawn downward. In this manner forcible stretching is continued until the dorsum of the foot can be brought almost into apposition with the crest of the tibia. When the operation has been completed, the foot should be perfectly limp. It is usually somewhat congested from the pressure of the fingers, but it is warm and the circulation is unimpaired.

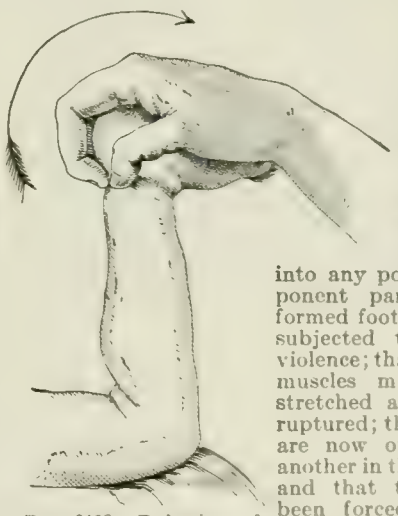


Fig. 2468.—Reduction of Equinus. (After Lorenz.)

One may assume that in the change that has taken place from rigid deformity to a limp foot that can be moulded into any position, the component parts of the deformed foot must have been subjected to considerable violence; that ligaments and muscles must have been stretched and, it may be, ruptured; that new surfaces are now opposed to one another in the articulations, and that the bones have been forced into approximately normal position. This method of treatment has a great advantage over the ordinary operative treatment, in that the entire foot has participated in the correction, instead of a limited portion, as when, for example, bone is removed by cuneiform osteotomy; and it has a second and almost equally important advantage, in that the immediate use of the corrected and yielding foot is possible in the

place of the necessary rest that must follow cutting operations. For these reasons forcible massage should be the operation of choice, and preliminary, at least, to more severe procedures in the treatment of resistant club foot in childhood. The only disadvantage of the operation is the actual labor which it necessitates on the part of the surgeon, usually twenty minutes or more of rather exhausting work.

The foot must now be fixed by a plaster bandage in an overcorrected position. It is first evenly covered with a layer of cotton and a bandage of canton flannel, and while it is held by the assistant, the plaster bandages are applied from the tips of the toes to the upper part of the thigh. It is important that the toes should not project beyond the bandage, because of the swelling that sometimes follows. It is important, also, that the foot should be held in the proper position while the bandage is hardening, and that it should not be manipulated to any extent after the bandage is applied, in order that no rigid wrinkle may press against the skin. The bandage is applied to the thigh in most instances in order that the tibia may be rotated outward to its normal position and held there, and because more effective fixation may be assured and greater pressure exerted on the foot in walking. To utilize this pressure to better advantage the bandage is made very thick beneath the sole, or a thin foot plate of wood may be incorporated in the plaster.

Fig. 2469.—The Feet Fixed in an Attitude of Overcorrection.

When the bandage is applied the position of the foot should be that of overcorrection of deformity, flexed beyond the right angle, twisted far outward, and the outer border should be elevated considerably beyond the level of the inner border (Fig. 2469).

One would suppose, after using the force that has been necessarily applied, that much pain and swelling would follow. This is, however, not the case. Often, on the following day, the patients are able to stand upon the foot, and always within the first week if the bandage has been properly applied. The pain following this operation is far more often caused by pressure of an ill-fitting bandage than by the violence that has been used. Thus one should be careful to remove sections of the bandage if it appears to cause undue discomfort. These pionts where pain is felt are usually the front of the ankle, the back of the heel, and the inner border of the great toe.

The immediate use of the foot is encouraged, and although only the heel and inner border bear weight directly, yet the pressure of the foot plate on the parts that do not come in contact with the floor is usually sufficient to mould the foot into its proper shape. If greater pressure is thought necessary, wedges of wood or cork may be attached to the sole of the plaster bandage so that all parts may bear weight equally. The bandage is covered by a stocking, a slipper may be worn indoors, and an ordinary overshoe for street wear.

The first bandage should be removed at the end of about three weeks, as by that time it will have become loose. The foot will then be found to be extremely flexible, and by an enthusiast it might be considered cured. But knowledge of its previous condition should make it evident that a much longer time is necessary to allow for its consolidation in the new position. At this time almost no evidence of the operation remains, except, it may be, slight discoloration of the skin. The foot is again held as far as possible in the overcorrected position and another plaster bandage is applied, usually as far as the knee only. This should remain for eight weeks, or longer if it is still unbroken. The patient uses the foot constantly, and is drilled in the proper method of walking, so that the muscles of the leg may become accustomed to the new and normal attitudes.

At the end of another month or more, the plaster is replaced by a brace to be worn inside the shoe, usually of the simplest description, consisting of an upright bar with a calf-band, attached to a steel sole plate by a joint that will allow dorsal flexion but checks extension at a right angle. This is applied because the dorsal flexors, after years of disuse, only slowly recover sufficient power to resist the action of the opposing group and the force of gravity.

The second stage of the treatment is now begun. This may be divided into a period of active treatment and one of supervision. The first or treatment stage consists in massage of the entire leg and of the foot to stimulate the growth of the atrophied muscles, and methodical manipulation of the foot several times a day by pushing it with the hand to the extreme of the range of motions possible immediately after the operation, viz., eversion, abduction, and dorsal flexion, in the same order as at the time of operation. At the same time the patient attempts voluntarily to carry out these motions by his own muscles, the power being supplied by the hand of the masseur. Slowly the muscles gain in strength and ability and when normal muscular power and balance have been regained the patient is practically cured; but for long afterward supervision is kept up of the patient's attitude, of the manner of using the foot, of the wear of the sole of the shoe, and the like, and by constant drilling and stimulation the attempt is made to restore the normal appearance and function.

One cannot exaggerate the importance of this after-treatment, and of supervision at least on the part of the surgeon. The active treatment may often be left to the parents. But constant supervision is necessary to keep this after-treatment, which seems so commonplace and simple, up to the proper pitch; and to assure one's self that the range of motion regained by the operation does not gradually become more and more restricted, even though the contour of the foot appears to be normal.

Forcible manual correction may be employed with advantage from the second to the tenth year, although the limits may be extended in either direction in special cases. In this operation, as described, the tendo Achillis is the only structure divided. There is no particular objection to subcutaneous division of other tendons or ligaments in connection with forcible manual correction; but in such prolonged manipula-

tion it is much better if the skin, which itself must be stretched, is unbroken and dry, rather than moist from the bleeding from punctured wounds. For this reason it is well to correct the deformity without extensive tenotomy if possible.

Treatment of Secondary Deformities.—In cases such as have been described a certain amount of secondary deformity of the leg is often present. Knock-knee rarely requires other treatment than daily manual correction in connection with the massage of the foot and leg.

Hyperextension at the knee will correct itself during the treatment of the foot, which, being fixed in an attitude of dorsal flexion, obliges the patient to walk with the knees slightly flexed. Inward rotation of the leg upon the thigh may be sufficient to require a brace, but, as a rule in childhood and adolescence, the patient has so long walked with exaggerated outward rotation of the femur that after correction of the deformity no inward rotation of the foot appears, even though inward rotation of the tibia be present. Osteotomy of the tibia, to correct the inward twist, is rarely necessary.

Malleotomy.—In confirmed club foot of the type under consideration, the chief obstacle to perfect correction may be the astragalus. This is often displaced forward, downward, and inward, so that only the posterior portion of its articulating surface is contained within the malleoli. In the cases of long standing the space between the bones may have become insufficient for the anterior and wider part of the body of the astragalus. In such instances, even after division of the tendo Achillis and the posterior ligament of the ankle, dorsal flexion still remains restricted, and examination shows that the astragalus still projects as before, although the foot has been forced into a position of apparent dorsiflexion and abduction. This apparent correction is the result of overcorrection at the mediotarsal joint, of outward rotation of the tibia upon the femur, and of backward displacement of the fibula. In such cases the malleoli may be separated from one another by dividing the ligaments that hold them in apposition.

A straight incision, about two inches long, is made on the outer side of the ankle directly over the anterior aspect of the articulation, the ligaments are divided and by inserting a thin chisel the bones are pried apart, and the astragalus is replaced in the proper position. This is usually easy if the restraining tissues on the posterior part of the ankle have been divided. The wound is then closed and the foot held in the overcorrected position by a plaster bandage. Complete correction of the varus deformity should, of course, precede this operation.

It would seem on first consideration that if immediate correction of deformity could be so easily accomplished in the confirmed case, it should be employed even in infancy. There are, however, practical reasons against it; first, because the foot is so small that it cannot be easily manipulated; second, because even after it is corrected it must be supported until the child begins to walk; and third, because the foot can be so easily straightened without an operation, which, even of so slight a character, is sometimes cause of much anxiety to the parents. For these reasons, although immediate reduction of deformity is a thoroughly practical and safe operation, it is rarely advised until a later time.

Subcutaneous Tenotomy.—The division of tendons and other tissues by the subcutaneous method has been mentioned incidentally, but as it has so long occupied an important, and even at one time the most important, place in the treatment of club foot, the operation and its effects may be described somewhat in detail.

Tenotomy, as has been stated, is performed for the purpose of removing an obstacle to the correction and overcorrection of deformity. In the acquired or paralytic form of club foot, one or more shortened tendons may be the chief obstacles to reposition, but in the congenital form, in which all the tissues have grown into deformity, the shortened tendons are by no means the only resistant parts, and tenotomy should be considered, therefore, merely as an incident in correction. In the ordinary treatment of infantile club foot, tenotomy may often be dispensed with, and in the great majority of cases division of the tendo Achillis is alone required.

When the tendon has been divided, the deformity is immediately overcorrected; thus the two extremities are separated to the extent necessary to allow the improved position. At the end of three weeks or more, when the first dressing is removed, the space will be filled with new material, and in another month the splice, which will be somewhat larger and thicker than the normal, should be strong enough for use. The slight thickening at the site of the operation may be felt for a year or more, but for all intents and purposes the new and lengthened tendon is perfectly normal, as is the function of the muscle of which it is a part.

The process of repair is somewhat as follows: Immediately after the operation the space between the divided ends of the tendon is filled or partially filled with blood; then leucocytes appear, which with those in the blood clot serve as pabulum for the plasma cells which migrate from between the fasciculi of the tendon and from the tendon sheath. The fibrin and red corpuscles of the clot are absorbed, the extremities of the divided tendon soften and become fused with the new material, which begins to take on the form and consistence of true tendon, and to separate itself from the adherent sheath. This new tendon differs from the normal structure in that the fibrous fasciculi are more irregular and its substance is more like scar tissue, but practically it is perfectly normal in its appearance and function.

Since the tendon sheath serves an important purpose in repair, it should be disturbed as little as possible, and for this as well as for other obvious reasons, subcutaneous tenotomy of the tendo Achillis, which is so prominent and so distinct from other important parts, is to be preferred; but if more extensive division of other tendons is required, the open operation is often indicated.

Division of the Tendo Achillis.—For this operation anesthesia is usually required, preferably by means of nitrous oxide gas, and it is hardly necessary to state that surgical cleanliness, even in so slight a procedure, is essential.

The instrument should be small and very sharp so that no force is required in the operation; the blade should be as long as the tendon is wide. The patient is turned upon the side or to the prone position, so that the foot may be held with the heel upward by the left hand. The position and size of the tendon are ascertained by careful palpation, and the knife is then inserted to its inner side, at about the level of the extremity of the internal malleolus. The flat surface of the blade is held parallel to the tendon, and it is passed beneath it until its point can be felt beneath the skin on the opposite side. The edge is then turned upward, and the tendon, being made tense, is divided by a sawing motion of the knife. When the division is complete, as indicated by the separation of the divided ends, the knife is withdrawn, and the minute opening in the skin, from which there is usually slight bleeding, is covered with a pledget of aseptic cotton. The foot is forced into dorsal flexion and is securely fixed by a plaster bandage. In applying the dressing one should take care that no pressure is brought upon the seat of operation, as this might interfere with the effusion of plastic material. As soon as the discomfort attending the operation has subsided the patient is encouraged to stand and to walk. Functional use, far from retarding repair, is, by

stimulating the circulation, an important agent in assuring firm and rapid union.

Division of the *plantar fascia* is not infrequently necessary and should be performed subcutaneously. The tenotome is inserted beneath the skin at about the center of the concavity to one or the other side of the central band of the fascia, which is divided by a sawing motion of the knife. The part is put upon the stretch, and other resisting bands to the outer and inner side are divided in the same manner; the cavus is then corrected by manual or instrumental force. The operation, like that upon the tendo Achillis, is practically free from danger.

Division of the *tibialis anticus* is not often necessary, as this tendon offers little resistance to the rectification of deformity.

The tendon of the *tibialis posticus* may be divided together with that of the tibialis anticus near the points of attachment. If the operation is required, it may be combined with simultaneous section of the *calcaneoscaphoid ligament*, with which are blended the anterior part of the deltoid and fibers of the anterior ligament of the ankle. (Parker: "The Astragaloscaphoid Angle.") According to Parker's

Fig. 2470.—Resistant Club Foot in Adolescence.

directions, the foot should be strongly abducted to make the parts tense. The tenotome is entered directly in front of the anterior border of the internal malleolus, its cutting edge being turned forward between the skin and the ligament. It is then turned toward the ligament, and the tissues are divided to the bone. The blade is then made to enter the interval between the astragalus and the scaphoid, and is carried downward and forward to divide the inferior part of the ligament and at the same time the tendons of the tibialis anticus and posticus.

The posterior ligament of the ankle-joint may be divided or sufficiently weakened, so that it may be ruptured after section of the tendo Achillis by passing the knife directly downward in the middle line upon the upper border of the astragalus.

Forcible Correction of Deformity by Means of Osteoclasts and Wrenches.—In place of manual correction of deformity greater force may be employed by means of osteoclasts or wrenches. There is this important

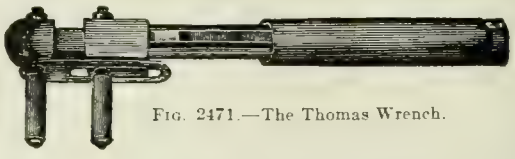


Fig. 2471.—The Thomas Wrench.

difference between the two procedures: force may be applied by the hands for as long a time as is necessary with but little danger of injury, while force applied by a machine must be momentary because of the pressure and strain on the parts where the leverage is exerted. Manual force, continuously applied, may be supposed to stretch the resistant parts, and although much less power is exerted it is often more effective than the sudden and momentary force of the wrench or osteoclast.

Correction by means of the Thomas wrench is one of the simplest and most efficient of these procedures. The wrenching may or may not be preceded by tenotomy, a point to be decided by the resistance of the parts. As a rule division of the tendo Achillis is alone necessary. The instrument is a simple heavy monkey wrench, of which the jaws have been replaced by two strong pins slightly bulbous at the ends to keep the covers of rubber tubing from slipping off (Figs. 2471–4474).

The wrench is applied to the inner side of the foot and screwed down, so that it may "bite" and hold its place firmly, for if it slips it is likely to abrade or tear the skin; then with considerable force the foot is twisted outward and upward. The "keynote" of the operation is so to wrench the foot that it loses its elasticity, and shows no tendency to recoil toward deformity. The foot is then placed in the best possible position and retained there by the Thomas foot splint or by a plaster bandage. In certain instances one may complete the rectification at one operation, but this is not usually attempted, the procedure being repeated at intervals of a few days until the deformity has been overcorrected. In very resistant cases eight or ten applications of force may be necessary. When the deformity has been rectified, the foot is held in the overcorrected position for several weeks by the splint or plaster bandage.

As a walking appliance, a simple upright of iron with a calf-band is applied to the inner side of the leg from a point just below

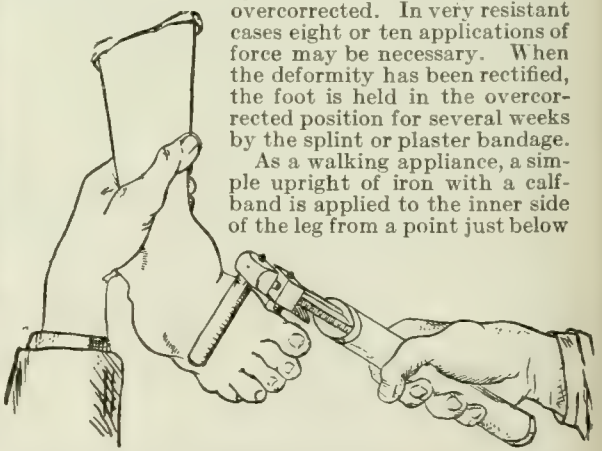


Fig. 2472.—The Thomas Wrench Applied to a Case of Talipes Equinovarus.

the knee to the heel of the shoe, into which it is inserted, as is the Thomas knock-knee brace. By bending the upright the foot may be kept in slight valgus, and this position is still further assured by making the outer side of the sole of the shoe thicker than the inner, so that the weight falls upon the inner border of the foot.

In many instances the walking brace may be dispensed with in the after-treatment, but a light brace is usually worn to hold the foot in the corrected position during the night, until the power of the abductors and dorsal flexors has been regained. Massage and manipulation are used in the after-treatment in the manner already described.

Properly applied the treatment is satisfactory and free from danger. Sloughing of the tissues caused by the pressure of the instrument or by the plaster bandages has been reported, but such accidents have not occurred in the extensive practice of Thomas and Jones.

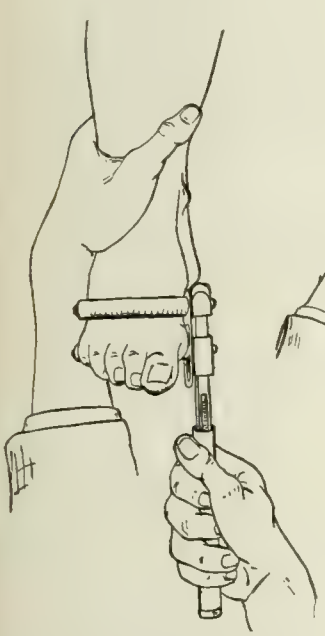


FIG. 2473.—The Deformity Partially Corrected by the Wrench.

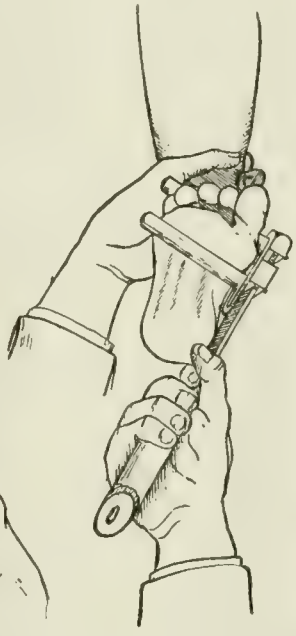


FIG. 2474.—The Deformity Fully Corrected by the Wrench.

Correction by Means of the Osteoclast.—The late Mr. Grattan, of Cork, used the osteoclast that goes by his name to crush and to overcorrect resistant club foot. The operation may include, besides the correction of deformity of the foot itself, fracture of the leg above the malleolus to turn the foot toward valgus, and a second fracture half-way up the limb, to overcome the twist of the tibia.

Other appliances constructed on somewhat similar principles may be employed. Of these the Lorenz osteoclast and the Bradford lever apparatus are the most effective.

The Open Incision Combined with Forcible Rectification of Deformity—Phelps' Operation.—When extensive division of soft parts is indicated, as in resistant cases, the open incision is to be preferred because of the opportunity thus offered for the recognition and for intelligent selection of structures that require division in the final correction of the deformity.

Phelps' operation is in all essential respects simply the division of the contracted parts through an incision on the inner border of the foot, combined with the manual or instrumental force sufficient to overcorrect the deformity. It is the most conservative of the more radical procedures, and by it even the most severe type of deformity in the adult can be corrected; that is to say, the deformity may be overcome and a serviceable foot may be assured to the patient. Perfect functional cure is not possible when deformity has become habitual after many years of neglect.

The steps of the Phelps operation are as follows: After proper surgical preparation the Esmarch bandage is applied. The tendo Achillis, and usually the posterior ligament of the ankle, are divided subcutaneously, and by manual or instrumental force the equinus is corrected as far as possible. An incision is then made on the inner border of the foot, just below and in front of the internal malleolus which is extended directly downward over the head of the astragalus to include the inner quarter of the sole. Through the incision all resistant parts are divided, according to Phelps, somewhat in the following order:

1. The tibialis posticus, and the anticus if it offers resistance.
2. The abductor pollicis.
3. The plantar fascia.
4. The flexor brevis digitorum.
5. The long flexor of the toes.
6. The deltoid ligament in all its branches.

During the successive division of the tissues repeated attempts are made to correct the foot, and only those structures are divided that present themselves as tense and resistant tissues when the foot is forcibly abducted.

In the adult type of club foot no attempt is made to recognize the different structures, but all the tissues on the inner side of the foot including blood-vessels and nerves, the deep ligaments, and occasionally the tendon of the peroneus longus muscle, are divided. Even then it is necessary to apply considerable force to correct the deformity. In rare instances the rectification of deformity necessitates osteotomy of the neck of the astragalus, or the removal of a cuneiform section from the os calcis. The object of the Phelps operation is, by the use of force and by division of resistant tissues, to overcorrect the deformed foot at one sitting, and as much force and as extensive division as are required should be employed by the operator.

When the foot can be held in the desired position without resistance, the wound is covered with Lister protective, the foot and leg are thickly covered with gauze and cotton, a plaster bandage is applied, and the limb is elevated. In younger subjects the patient may walk upon the corrected foot in a few days. The large gaping wound closes by granulation in from one to three months; in many instances healing is practically completed under the first dressing.

By this operation the foot, even in severe cases in adult life, may be made straight in appearance. It is evident, however, that in such cases the correction of the deformity of the bones is by no means always perfect, for the fore foot may be simply twisted outward and upward while the astragalus and os calcis may remain in an approximation to their original deformity. After thorough over correction by the Phelp method the danger of recurrence of deformity in the adult and adolescent type of club foot is not great, and in many instances support other than that of the plaster bandage for several months after the operation may be unnecessary; but in childhood the ordinary precautions in after-treatment to prevent relapse will be necessary.

Operations on the Bones.—Osteotomy of the neck of the astragalus, as a supplementary part of the operation of forcible correction, has been mentioned. In certain instances, particularly in the adolescent or adult type of deformity, the displaced astragalus may offer such an obstacle to correction that its removal is indicated.

Astragalectomy.—The astragalus is usually removed by means of an incision passing over its most prominent part, in a direction forward and downward from the tip of the external malleolus, between the tendons of the peroneus brevis and peroneus tertius. The soft parts are drawn aside, the ankle and astragaloscaphoid joints are opened, and the attachments to the scaphoid, and, as far as possible, those at the inner and outer border, are divided. The foot is next

adducted so that the head of the bone may be seized with forceps and drawn upward; the interosseous ligament and the internal lateral ligament may then be divided with curved scissors. If the varus has been entirely overcome by preliminary stretching the foot may be easily fixed in the overcorrected position but in most instances a wedge must be taken from the neighborhood of the calcaneocuboid articulation in order to overcome completely the residual varus.

Cuneiform Osteotomy.—The removal of cuneiform sections of bone from the outer border of the foot is sometimes necessary, but the operation should be secondary to other methods of correction. The aim should be to lengthen contracted and shortened tissues on the inner border of the foot, to the extent required for reposition; not to remove bone to accommodate these shortened tissues. If this has been shown to be impossible by ordinary means, then removal of bone may be indicated, but this is rarely necessary in childhood. If sufficient bone is removed from the adult foot to allow of perfect correction of the deformity, relapse is not usual; but in childhood, as has been stated, no operation will enable one to dispense with after-treatment and supervision.

The treatment by cuneiform osteotomy is sufficiently simple. A wedge of bone, usually part of the projecting body of the astragalus and of the os calcis, of sufficient size to permit complete overcorrection of its deformity, is removed. The surfaces are apposed by the correction and the foot is fixed in a plaster bandage. In the treatment of severe cases in the adolescent and adult, it is well to divide correction procedures into stages in order to permit the accommodation of the circulation to the new attitude. Thus partial correction by force and tenotomy should precede by a week or more the final overcorrection by astragalectomy, osteotomy, and the like.

Simple Mechanical Rectification of Deformity in Walking Children and in those of Older Growth.—It has been stated that simple mechanical rectification of deformity was possible even up to adolescence, but that the time required for such treatment, usually extending over several years, as a rule excluded it from consideration.

The simplest mechanical treatment is that by which the foot is slowly forced from equinovarus into equinovalgus by a brace on the lever principle, which is at first shaped to the deformity, and is then gradually straightened as the resistance diminishes. When the midpoint has been passed between varus and valgus the weight of the body aids in the correction of the remaining varus and equinus. The modification of the Taylor brace used by Judson, an advocate of pure mechanics in the treatment of club foot, will serve to illustrate the type of apparatus which, with slight change, may be employed to correct or to support the weakened or deformed foot.

The brace consists of an upright, a flat tapering bar of mild steel, a foot-plate of steel from 18 to 16 gauge and a strong calf-band. The shape of the brace, the method of its attachment to the legs by straps of webbing, and its effect in gradually changing the attitude of the foot from varus to valgus are shown in the accompanying figures (Figs. 2475–2482).

The upright is firmly riveted to the foot plate in the angle of deformity, so that the patient walks upon his toes; as the equinus is decreased by the influence of the weight of the body, this angle is lessened.

The important points are, that the brace should be strong enough to hold its place under the strain of use, and that the foot shall be firmly secured to it, whether one or many straps of webbing are required, as may be seen in the figures. The use of massage and manipulation is of course combined with the mechanical treatment.

By persistent attention to the details of treatment satisfactory results can be obtained by this method in the less resistant cases, even in adolescence.

Recapitulation of the Principles of Treatment of Congenital Talipes Equinovarus.—The object of treatment is to overcome and to overcorrect the deformity at as early a period of life as is possible, and as quickly as possible. The object of overcorrection is to overcome all the resistance of the tissues that may even in the slightest degree limit the normal range of motion in any direction. The foot must be supported in the overcorrected position until the recoil of the tissues toward deformity is no longer present.

It must be supported in the proper relation to the leg, and at a right angle with it, until the muscular

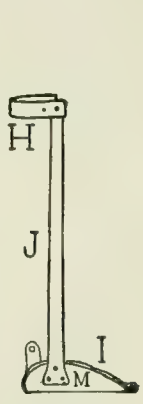


Fig. 2475.

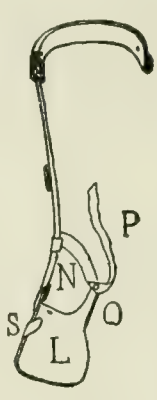


Fig. 2476.

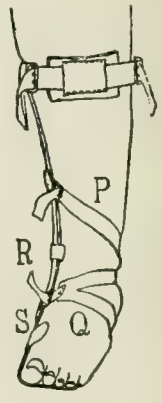


Fig. 2477.

Fig. 2478.

Fig. 2479.

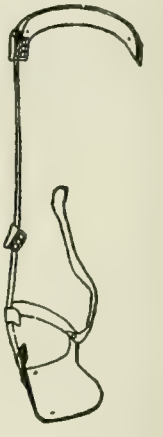


Fig 2480.

Fig. 2481.

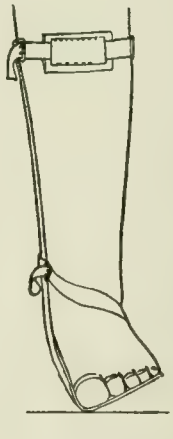


Fig. 2482.

balance has been reëstablished by stimulation of the weaker, and by limitation of the activity of the stronger, muscles, and until transformation of the internal structure has been completed.

If efficient mechanical treatment is applied at the proper time, that is to say, in earliest infancy, no operation, other than division of the tendo Achillis, will be required.

If the deformity is not corrected or is but partially corrected, when the child has begun to walk, some form of operation is as a rule indicated; but division of the resistant tissues must always be combined with the employment of sufficient force to accomplish the desired result, viz., overcorrection of the deformity. Manual correction, applied in the manner described, is the most efficient means of attaining this object. No instrument can equal the hand, and the force that can be applied by the hand is sufficient in all the ordinary cases in early childhood, and in combination with subcutaneous division of the more resistant tendons and ligaments, even in later childhood and adolescence.

Forcible correction by the Thomas wrench under the same conditions is an efficient treatment, but there is a manifest disadvantage in submitting a patient to a succession of operations, even of so slight a character, if immediate overcorrection can be attained by other means.

The Phelps' operation, which combines thorough division of the resistant parts with the application of proper force to overcorrect the foot, is the operation of selection for the more resistant cases in adolescence, in adult life, and in extremely resistant cases in childhood. It is indicated particularly in cases of resistant varus.

Astragalectomy and cuneiform resection are never indicated as primary operations, but one or the other or both in combination may be necessary in the rectification of the deformity when other means have failed.

Complete cure of deformity, even in the later years of childhood, is possible by means of braces alone, but such treatment is very tedious. It requires not only the continuous supervision of the skilled surgeon, but the intelligent and persistent cooperation of the parents. The results are in no way superior to those attained by more rapid methods, while the disadvantages of long-continued use of braces are sufficiently obvious. To the popular faith in braces as a cure-all of deformity, and to the unintelligent use of braces, may be ascribed, now as in former times, the failure of treatment of this eminently curable deformity. This statement seems justified, even when balanced by the equally fallacious belief, so prevalent among physicians, that an operation, if not synonymous with cure, is, at least, the essential part of the treatment.

Rectification of deformity, by whatever means, simply completes the first stage of treatment. Perfect cure can be assured only by attention to the small details of after-treatment, by checking the slightest impulse toward deformity, and by guiding the unbalanced foot toward perfect functional use.

Other Varieties of Congenital Talipes.—Forms of congenital distortion of the foot other than equinovarus are not uncommon, but as a rule these deformities are so slight, and, as compared to equinovarus, so easily remedied that they are relatively of little importance (Fig. 2483). This distinction does not apply, however, to acquired talipes, of which the various forms will be considered in other sections.

Congenital Talipes Varus.—This deformity often appears to be an incomplete form of equinovarus, but in some instances there is simply a slight inward twist of the foot without supination; in fact, the fore foot seems to be drawn inward by the active movement of the great toe, which in such cases seems almost prehensile (see Pigeon Toe, in article *Foot, Deambulation of the*). In the more marked form the foot is adducted and inverted, and the tissues are very resistant.

The slight grades of deformity may be treated by simple manipulation, and if deformity remains after the first year, the shoe will, as a rule, correct it. The more marked varieties must be treated like the varus deformity of club foot, until the varus has been transformed into valgus. The after-treatment is the same as that for ordinary club foot.

Fig. 2483.—Congenital Talipes Varus.

Congenital Talipes Equinus.—This is a rare congenital deformity, about half as common, according to the statistics, as varus. The term equinus implies that dorsiflexion is limited, but that the foot is not deviated to one or the other side (toward valgus or varus). In congenital equinus the deformity is as a rule slight, and it may be overcome usually by simple manual force applied frequently. In the more resistant type, mechanical correction, or tenotomy, followed by overcorrection and support, may be necessary.

Congenital Talipes Calcaneus.—Congenital calcaneus is comparatively rare. As a rule the heel is prominent, the foot is habitually dorsiflexed, and the dorsum can be brought into contact easily with the crest of the tibia (Fig. 2484). The exaggerated cavus that is usually present in acquired calcaneus is absent. Occasionally the deformity is accompanied by hyperextension of the knee, and if, as in many instances, there is a history of breech presentation, it may be inferred that the attitude before birth was one of extreme flexion of the thighs upon the abdomen, while the anterior surfaces of the extended legs were pressed closely to the ventral surface of the body, the feet being fixed in an attitude of dorsiflexion. And in other instances it is accounted for in great part by backward bowing of the tibia. As a rule the deformity is slight, and the resistance of the tissues on the anterior aspect of the leg can be overcome easily by massage and manipulation. The foot should be gently forced toward plantar flexion several times in

the day, and the weak muscles of the calf should be stimulated by massage.

Cure may be hastened by the use of some simple form of retention splint to hold the foot in plantar flexion until the posterior group of muscles has recovered its power. Tenotomy or other operative treatment is not often necessary. The backward bowing of the tibia may be overcome by manipulation and apparatus or by immediate forcible correction.

Fig. 2484.—Congenital Talipes Calcaneus.

Congenital Talipes Valgus.—Congenital valgus is somewhat more common than the preceding varieties. Not infrequently it is combined with a slight degree of calcaneus or equinus. The resistance of the contracted tissues is not great and the deformity may be overcome, in most cases, by persistent manipulation. If the muscular power is sufficiently unbalanced to warrant it, the foot should be held in the over-corrected position (varus) for some time.

Congenital valgus is one form of what is known as weak ankle, and it frequently passes unnoticed until the child begins to walk. If at that time, in spite of massage, the muscles appear weak or the foot inclines outward when weight is borne, it is well to make the sole of the shoe wedge-shaped, the thicker part (one-quarter of an inch) on the inner side. In more persistent cases, a brace may be necessary, as described in the treatment of the acquired variety (see the Weak Foot).

Talipes equinovalgus is less common. This must be treated as the other varieties by complete over-correction of deformity, manual or otherwise, by massage, and subsequently by support if necessary.

Calcaneovalgus, calcaneovarus, equinocavus, valgocavus, valgocavus and cavus are extremely uncommon. If treated early by persistent forcible massage, these, as well as nearly all slighter grades of congenital deformity, may be corrected or cured even, before the child begins to walk.

Congenital Deformities of the Foot Associated with Defective Development.—*Talipes Equinovalgus Associated with Congenital Absence of Fibula.*—This is a rare deformity, but the most common of this class. The foot at birth is usually in an attitude of well-marked and resistant equinovalgus. The limb is somewhat shorter than its fellow, the femur too in slight degree contributing to the deficiency, and the tibia is often bent sharply forward, sometimes to an acute angle, at a point somewhat below the center, as if it had been broken in utero. At the most prominent point the skin may be adherent or it may present a dimpled appearance. In some instances the formation of the foot is perfect, but more often one or more of the outer toes, with the corresponding metatarsal bones, are absent.

The cause of deformity associated with absence of bone must be either an original defect in the germ or it may be due to interference with its development. In some instances amniotic adhesions may be one of the predisposing causes; the sharp bend in the tibia, so often present, may be due to lessened resistance of the defective part.

Treatment.—The indications for treatment are to correct the deformity of the foot in the usual manner. The bend in the tibia may be straightened by manipulation and splinting, or by osteotomy if necessary. When the patient begins to walk the foot must be supported. A light steel upright on the outer side of the leg, provided with a T strap to hold the ankle against it, may be used to supply the place of the missing fibula. The growth of the tibia and to some degree of the femur is interfered with and a final shortening of three or more inches may be expected.

Talipes Varus or Equinovarus Associated with Congenital Deficit of the Tibia.—Defective formation of the tibia is much less common than that of the fibula. In most cases the femur is somewhat shortened and its lower extremity is imperfectly developed. The foot is practically always in an attitude of varus. The toes may be normal but in a number of instances one is found to be lacking.

The prognosis, as regards a useful limb, is extremely bad. The growth of both the thigh and the lower leg is much retarded, and it is almost impossible to balance the foot upon the fibula by any form of brace.

The ordinary treatment, after the correction of the deformity of the foot, has been to resect the extremities of the femur and the fibula to produce ankylosis between the bones, but in the cases in which the thigh s approximately normal an artificial limb may be adjusted to cover and lengthen the deformity.

Deformity of the Foot Associated with Absence of Bones.—The leg bones may be perfectly formed, but one or more bones of the foot itself may be absent.

Fig. 2485.—Congenital Talipes Valgus—"Flat-foot."

In these cases, after the reduction of the deformity, a support to hold the defective foot in its proper relation to the leg must be used.

The foot may be divided into two parts so that it resembles a lobster claw. Supernumerary toes, or deficiency of toes, or hypertrophy of one or more of the toes, with or without corresponding overgrowth

of the foot or leg, are not extremely uncommon. These deformities must be treated on ordinary surgical principles.

Constricting Bands.—Tightly constricting bands of scar-like tissue, which cause deep indentations in the flesh of the foot or leg, are sometimes seen. These are supposed to be caused by amniotic adhesions. "Spontaneous amputations" of toes, or of the foot itself, are due to the same cause.

In ordinary cases the bands require no treatment, but if they interfere with the nutrition of the foot, they may be removed.

Congenital Edema of the Feet.—In rare instances, sometimes in combination with deformity, the tissues of the feet appear to be edematous, although the circulation seems to be perfect. The condition is apparently due to obstruction of the lymphatic circulation. It should be treated by massage and compression.

Spina Bifida and Talipes.—Talipes coexisting with spina bifida should be treated as are other forms of club foot. If paralysis of the lower extremities be present, as is often the case, the corrected feet must be supported as in the ordinary forms of paralytic deformity.

Acquired Talipes.—It has been stated that equinovarus is by far the most common of the congenital deformities of the foot and that as compared with it the other forms of talipes are of slight importance.

In the acquired varieties of talipes, equinovarus is much less common (30 per cent. of the total number as contrasted with 77 per cent. of the congenital deformities). Acquired equinus comes next in frequency (25.9 per cent. as compared with 2.3 per cent. of the congenital deformities), and every variety and combination of distortion finds its representative in acquired talipes as may be seen in the table of statistics.

Etiology.—The cause of acquired talipes is almost always paralysis. In the table of statistics it may be noted that in 82.8 per cent. the paralysis was of spinal origin (anterior poliomyelitis); in 11.3 per cent. the lesion was of the brain, the talipes being a part of the deformity of hemiplegia or paraplegia. A few cases were caused by local disease of the nerves, and the remainder, 5.4 per cent., were of traumatic origin.

The distinction between congenital and acquired talipes is important. In the congenital form the disability is due simply to local deformity, and when this has been overcome a perfect cure may be expected. In paralytic talipes the rectification of deformity is but a part of the treatment, and perfect cure is impossible except in that small proportion of cases in which the spinal cord has sustained no permanent injury, or in which the deformity was the result of some slight or passing disability or disease.

Congenital deformity cannot be anticipated or prevented; acquired deformity is an evidence that protective treatment has been neglected. It is a result, therefore, that may be foreseen and prevented.

The characteristics of anterior poliomyelitis are described elsewhere. In its effect upon the foot the usual sequence is somewhat as follows: Immediately after its onset the paralysis is usually widespread, affecting the entire limb, for example. Then follows a period of partial recovery, after which the amount of damage that the spinal cord has sustained may be estimated. It is during the period of partial recovery, the six months or more following the attack, that contractions which lead to deformity occur. If, for example, the anterior group of leg muscles is paralyzed, the foot habitually hangs downward, a position due to the force of gravity and to the contraction of the unaffected posterior group. If this attitude is allowed to persist, the tissues accommodate themselves to the new position; the muscles that are never extended to their normal limit become structurally shortened, while the paralyzed group becomes correspondingly longer. Even within a few days after the onset of the paralysis the evidences of advancing deformity appear. The contracted tissues resist passive motion in the direction opposed to the habitual attitude, and the child shows evidence of pain if force is used to increase the limited range of motion. As has already been stated, paralytic talipes is an unnecessary deformity. It may be prevented by supporting the paralyzed part in a right-angled relation to the limb, and by systematic passive exercise throughout the entire range of normal motion.

Anterior poliomyelitis is most common during and after the second year of life or when the child has already begun to walk. When the first and more general effect of the disease has passed away, the child again uses the disabled limb as best it may; thus the distortion of the foot is increased and confirmed by the weight of the body and by functional use in the abnormal attitude.

The final deformity in a particular case may be predicted from the knowledge of the function of the muscle or muscles which has been lost. For example, paralysis of the tibialis anticus, the most powerful dorsiflexor and adductor of the anterior group, must result in equinovalgus; paralysis of the tibialis posticus induces valgus. If the peronei are affected varus will follow. Paralysis of the calf muscle will cause calcaneus. Paresis or paralysis of the entire anterior group will cause equinus. If all the muscles are paralyzed, what is called a "dangle foot" is the result. The foot hangs from the atrophied leg with but little tendency to deformity unless the limb is used, when it is usually forced into an attitude of equinovarus or valgus.

A slight degree of paralysis may cause so little disability that it may be entirely overlooked, and its later effect in causing disability or deformity may not attract attention for many years. This fact has been mentioned in the etiology of the contracted foot.

Differential Diagnosis between Congenital and Acquired Deformity.—The history itself is usually sufficient, for deformity of the foot at birth is never overlooked by the mother. Acquired talipes is practically always preceded by a history of disease, or weakness, or injury which was soon followed by slight and afterward by increasing and confirmed deformity.

In paralytic talipes (anterior poliomyelitis), there is evidence of paralysis in loss of function of certain muscles, as shown by electrical stimulation or by pricking the foot with a pin; later, in the atrophy of the muscles, and the evident change in the nutrition and diminished growth of the limb.

Only in extreme and untreated cases of congenital deformity of long standing could there be difficulty in distinguishing between the acquired and the congenital deformity. In rare instances, it is true, paralysis may be present at birth, due to intrauterine disease or to defect in the nervous apparatus. In such cases the cause of the paralysis is usually apparent (spina bifida, or spastic paralysis associated with defective cerebral development), and the treatment does not differ from that of the acquired form.

Acquired Talipes Equinus.—In well-marked cases, the foot is plantar-flexed to its full limit, and it is held in this attitude by the shortened structures on the posterior aspect of the leg. The patient walks upon the heads of the metatarsal bones, the toes being dorsiflexed to accommodate the attitude. The arch of the foot is increased and the tissues of the sole, particularly the plantar fascia, are contracted. The entire foot is broadened and shortened, the breadth being especially increased across the metatarsal region. On the dorsal surface the cuneiform bones are prominent, and the head and body of the projecting astragalus may be felt beneath the skin. Occasionally, in cases of extreme deformity, in which all the anterior muscles are paralyzed, the toes may be plan-

tar-flexed so that the patient walks upon their dorsal surface.

The cavus or exaggerated arch is due primarily to the plantar flexion of the fore foot at the mediotarsal joint, and in many instances this dropping of the fore foot is largely responsible for the equinus, for the os calcis is rarely plantar-flexed to the degree commonly found in the ordinary congenital equinus.

Fig. 2486.—Acquired Talipes Equinus.

In the slighter degrees of the deformity the toes are usually dorsiflexed, an attitude due to the overaction of the extensor longus digitorum and proprius pollicis, as aids in dorsiflexion.

Etiology.—Equinus in the slighter degrees is the most common of the forms of acquired talipes, and it is not at all infrequent as a result of other affections than anterior poliomyelitis, although this is by far the most important cause. The nerve supply of the anterior muscles of the foot seems especially susceptible, and toe-drop from neuritis of various types is not at all uncommon. As a sequel of infectious diseases it has been mentioned as an explanation of the slight forms of equinus first noticed after recovery from such affections.

Equinus may be a result of cerebral disease or even, in rare instances, of progressive muscular dystrophy or locomotor ataxia. It is sometimes induced by habitual posture, as after long confinement to the bed for the treatment of fracture, or during the treatment of hip disease by apparatus. The contraction may be an effect also of voluntary posture as in compensation for a short limb. It is a very common result of neglected disease at the ankle joint, and it may be due to direct injury; but as of paralysis, so of these less frequent causes it may be said that equinus may be prevented by protection of the weakened part

The changes in the internal structure of the foot are secondary to the deformity and are most marked in the cases beginning in early life and of long standing; the tissues on the long side are lengthened and attenuated while those on the short side become contracted. The bones themselves are but little changed in gross appearance, but the articulating surfaces are in different relation to one another; for example, only the posterior aspect of the astragalus is in relation to the tibia, while only the lower part of its anterior surface articulates with the scaphoid.

In all cases of equinus there is a strong tendency toward lateral deviation to varus or valgus, particularly in those caused by paralysis.

Symptoms.—If the limb is actually shorter than its fellow, and if the foot is firmly fixed in the deformed position, surprisingly little discomfort or disability may be experienced other than from corns or calluses beneath the heads of the metatarsal bones. If the limb is not shorter, the additional length caused by the equinus must be compensated by an upward tilting of the pelvis, which may cause discomfort in the lumbar region. The gait is always awkward, giving the impression as of stepping over an obstacle. If the foot is not fixed but simply hangs downward when it is lifted, the gait is very awkward because of the insecurity and because of the exaggerated flexion of the knee at each step, necessary in order that the pendent foot may not drag upon the ground.

If the equinus is extreme, the limb is usually flexed at the knee when in use; if the equinus is slight, the strain resulting from the limitation of dorsal flexion is felt at the knee, and in childhood at least there is often a well-marked tendency to overextension, or recurvation, caused by the effort to place the sole flat on the ground.

In the slight forms of equinus, discomfort about the calf is experienced; the limitation of dorsal flexion

Fig. 2487.—Slight Equinus Caused by Paralysis of the Tibialis Anticus Muscle. The distortion of the toe due to the overuse of the extensor proprius hallucis is characteristic.

causes a rather shortened stride and awkward gait, while an unguarded step throws a sudden strain upon the rigid heel cord which is felt as a shock and strain through the leg and body. Very often the patient complains of pain at the metatarso-phalangeal joints (anterior metatarsalgia), and if the equinus is accompanied by a slight degree of valgus, symptoms of the weak foot may be present.

The *Prognosis* depends of course upon the cause of the deformity. If it is simply the result of posture, or

if it is secondary to neuritis, permanent cure may be expected. In many cases caused by anterior poliomyelitis recovery, complete or partial, has taken place; yet although voluntary control of the muscles has been regained it cannot be exercised because the foot is held in the distorted position by the contracted tissues.

In such instances practical cure may be predicted if, after the overcorrection of deformity, sufficient time is allowed for the lengthened and atrophied muscles to regain their proper length and volume.

Treatment.—In the somewhat uncommon cases of fixed equinus combined with a short leg and not attended by discomfort, no treatment is required other than a shoe so built that the heel may support a part of the weight. In the more extreme cases in which the leg is short and the foot is atrophied, an extension foot attached after the manner of an artificial leg may be worn with comfort and with but little evidence of deformity.

In the ordinary cases, whether permanent cure is expected or not, the rule holds good that the heel should bear the weight of the body and that the range of dorsal flexion should not be limited when the calf muscle retains its power. If the nervous apparatus has received permanent injury, the foot must be supported after the deformity has been rectified; but even in this class the gait may be improved and the discomfort relieved by removing the restrictions to normal motion. The slighter degrees of equinus, such as those that are seen soon after the onset of anterior poliomyelitis, may be rectified by simple manipulation and retention in a splint or in plaster of Paris.

The weight of the body may be utilized as a means of overcoming slight equinus, when the foot is held in its proper relation to the leg by a brace which extends above the knee; but this tedious method has but little to recommend it in ordinary cases. The elastic tension of straps and bands attached to a brace or to the foot itself by means of adhesive plaster is of some service in slight cases, but by far the most effective method is the immediate reduction of the deformity by a simple forcible manipulation under anesthesia, or by tenotomy combined with forcible manipulation, or by wrenching.

Immediate Correction of Deformity.—Attention has been called to the cavus as an accompaniment of confirmed equinus, and whenever one attempts to correct the deformity by force, the exaggerated arch should be reduced to its normal depth, otherwise the foot will appear stunted and deformed.

One of the most effective means for overcoming the cavus is the Thomas wrench. The contracted bands of the plantar fascia are first divided subcutaneously, the wrench is then fixed to the foot, and, with sudden force exerted against the resistant tendo Achillis, the foot may be straightened, the deep ligaments being ruptured or stretched to the proper degree. The tendo Achillis is then divided, and the foot having been dorsiflexed is fixed by a plaster-of-Paris bandage. As the patient is encouraged to walk upon the foot as soon as possible, the weight of the body forcing the relaxed tissues against the unyielding sole, completes the flattening of the arch. In many of these cases the knee has been overextended by use in the deformed attitude, so that the habitual flexion necessary to bring the dorsiflexed foot upon the ground during the two months allowed for the complete union of the divided tendon is of benefit as it serves to correct this secondary weakness and deformity.

If the toes are contracted the shortened tendons on the dorsal surface should be divided. They should then be forcibly straightened, flexed to the full limit, and fixed in this attitude by the plaster support.

The importance of the immediate relief of the strain of the deformed position upon the weak anterior group of muscles, together with the complete relaxation of the overstretched tissues which allows the "slack to be taken in" during the long rest in the overcorrected position, is not generally appreciated. Whenever the weakened muscles after paralysis show by tests, electrical or otherwise, that they have recovered their power in part, this treatment should be that of selection. The application of electricity or other form of stimulation to muscles that are unable to exercise their function because of contraction of opposing tissues is useless. Nor is any form of artificial stimulation equal to that of the functional use, which is made possible by the removal of the deformity and by the employment of proper support.

In many instances after the equinus, which more often than any other deformity is the result of slight or temporary disability of the anterior group of muscles, has been corrected in the manner described perfect cure seems to have been attained when the plaster bandage is finally removed. But even in such cases the application of a simple support to hold the foot at a right angle with the leg for several months is an advantage. The after-treatment by massage, muscle-beating, electricity, and the like, combined with methodical passive movements to the limit of dorsal flexion to guard against recontraction of the calf muscle, should be continued for a long time, or until the muscular balance has been regained.

The same form of support is necessary in cases of hopeless paralysis, to hold the foot at a right angle with the leg. The common form is a simple steel sole plate of sufficient size to support the foot and the toes, if their muscles are paralyzed, attached to a light upright provided with a calf band. The upright is usually applied on the inner side of the leg where it is least noticeable. At the ankle there is a "stop joint," which allows dorsiflexion but prevents the toe-drop. This, when properly fitted, can be placed inside the ordinary shoe, as the paralyzed foot is usually somewhat smaller than its fellow. If the toes do not need support, the upright can be attached to the outside of the shoe and the foot plate may be dispensed with; or the upright may be concealed by introducing it inside the shoe to a joint sunk in the heel; the toe-drop being prevented by straps passing from the front of the upper leather of the shoe to the calf band.

Equinus due to posture or disease may be cured by simple correction of the deformity. That due to fracture, when the deformity is caused by displacement of the bones, may be treated by direct operation, removal of the astragalus being in such instances the most efficacious remedy.

Acquired Talipes Calcaneus.—Acquired talipes calcaneus is much less frequent than equinus and it is almost always of paralytic origin (anterior poliomyelitis).

There are several varieties or grades of the deformity. In the early stage, and especially if all the muscles of the posterior group have been paralyzed, the foot assumes an attitude of slight dorsiflexion and the range of plantar flexion is gradually lessened by secondary contractions. This variety resembles closely the congenital form. In the ordinary and typical form of calcaneus, when fully developed the patient walks, as the name implies, on an hypertrophied heel. The arch is much increased in depth, and the fore foot is atrophied and useless.

The development of the deformity is somewhat as follows: The support of the calf muscle having been lost, the os calcis, gradually changes from a somewhat horizontal to a perpendicular position. It stands on end so that its posterior surface becomes inferior. The projection of the heel is lost and it lies in the plane of the atrophied calf. The change in the position of the os calcis increases the distance from the malleoli to the base; thus calcaneus, though in less degree than equinus, makes the limb longer. The turn-

ing of the os calcis on end shortens the foot and increases the arch. In many instances there is no permanent dorsiflexion or elevation of the fore foot, although in all the range of plantar flexion is limited. In this class the power in the remaining muscles of the posterior group is probably sufficient to counteract the contraction of the dorsiflexors. Cavus is thus a direct effect of the displacement of the os calcis. If the entire posterior group of muscles is paralyzed, while the anterior muscles are unaffected, the foot will be somewhat dorsiflexed and the cavus will be less marked. If the calf muscle only (gastrocnemius and soleus) is paralyzed, the remaining muscles of the posterior group will counterbalance the dorsiflexors and at the same time increase the cavus. In some instances the calf muscle is alone affected, in others one or more of the anterior muscles may be paralyzed also, in which case the foot is usually turned toward varus or valgus. The changes primarily caused by the paralysis and by unopposed muscular action become fixed by habitual use and by secondary adaptation of the tissues. The heel only is used in walking, and the area of callus which marks the weight-bearing surface becomes much enlarged, while the fore foot and toes,

Fig. 2488. Acquired Talipes Calcaneus

which have but little functional use, become atrophied, a mere appendage to the enlarged heel.

Symptoms.—The gait isowkaard and inelastic; the patient, who is, as it were, "ham-strung," stamps along upon the insecurc support of the heel in a manner which is easiyy recognizable by one familiar with the disability. The changes in the internal structur of the foot, the inevitable adaptations to the deformity do not call for special description; the disused bones atrophy together with the other tissues and new articulating surface from to accommodate the necessities of functional use.

Treatment.—When the diagnosis of paralysis of the calf muscle is made one may predict, unless recovery takes place, a deformity such as has been described. This deformity may be prevented by proper support, by massage, and by methodical stretching of the tissues that have a tendency to contract. The form of brace used for walking and for support should be provided with a sole plate, upright, and calf band, as already described in the treatment of paralytic equinus. If motion is allowed at the ankle it should be in plantar flexion only, the stop being the reverse of that used in equinus, or as this form of check entails much strain upon the brace, the joint may be omitted as in that form use by Judson. Thus the strain removed from the weakened tissues is borne by the anterior surface

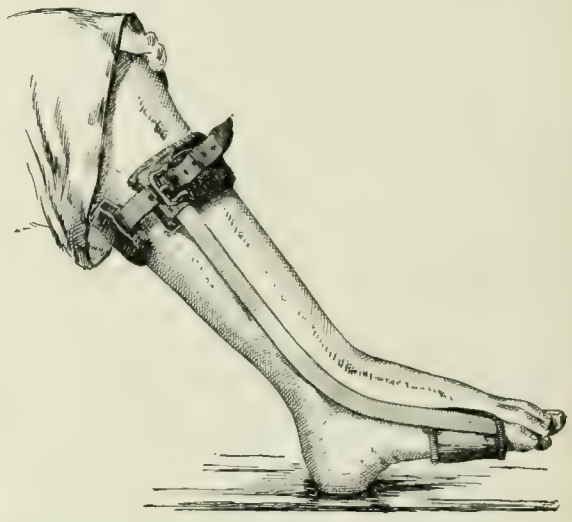


Fig. 2489.—Whitman's Brace for Talipes Calcaneus. Two lateral bars of thin steel connected by a foot plate and anterior leg band. The brace is supported by the shoe which should be elevated sufficiently at the heel to hold the foot in slight equinus.

of the leg. Other forms of braces provided with elastic bands to supply the place of the calf muscle are sometimes used, but as a rule the improvement in gait hardly compensates for the trouble in adjustment or the conspicuousness of the appliance.

Fig. 2490.—The Normal Foot.

Operative Treatment.—When it has become evident that there is possibility of recovery from the paralysis, particularly if deformity is increasing, and as a

primary measure in all cases of advanced deformity operative treatment is indicated.

The analysis of talipes calcaneus indicates that the astragalus, the center of uncontrolled motion, or insecurity, forms also the salient part of the deformity. Its removal is indicated, therefore, as the essential preliminary to permanent relief. The laxity of tissue thus obtained enables one to displace the foot backward, and to implant the malleoli on its basic structure near the center. This equalizes the leverage and checks dorsal flexion by direct impact of the tibia with the scaphoid. Tendon transplantation, usually of the peronei, is a useful supplement to restore in some degree the power of plantar flexion.

Fig. 2491.—Talipes Calcaneus.

By this procedure a range of serviceable movement is restored and deformity is reduced without violence. In fact, a moderate degree of cavus is of advantage in preserving symmetry and the excess is reduced by the transference of the pressure on the foot, whose weight-bearing capacity has been restored. The operation, although most successful in cases of extreme distortion, is also effective as a preventive of progressive atrophy and deformity, and if it is properly performed, the results, both as to appearance and function, improve with the lapse of time.

Fig. 2492.—Illustrating the Immediate Effect of the Wihtman Operation. See Fig. 2941.

In all these particulars it presents a striking contrast to other methods of treatment. For example: All operations for the correction of deformity are palliative in the sense that support is required to prevent relapse and to aid function. The same is true of tendon transplantation, as is indicated by comparison of the power of the calf muscle with that of the feeble lateral group that can be utilized to replace it. But one operation need be seriously considered in comparison. This is arthrodesis, by which security is obtained at the expense of motion, with consequent muscular atrophy. At best its range is far more limited, since operative ankylosis is impracticable until late childhood. Nor is it adapted for the more extreme type of calcaneus with lateral distortion. Even reduction of the cavus may require cuneiform resection of the tarsus as in Jones' operation. In successful cases, the foot is fixed at a right angle to the leg, or oftener in slight dorsal flexion, so that the weight, as before, is supported in great part on the heel. If, therefore, as in many instances, shortening of the limb is sufficient to require compensation, an unsightly cork sole must be worn, as contrasted with a higher heel, or in more extreme cases, an extension shoe, which may be applied when plantar flexion is retained.

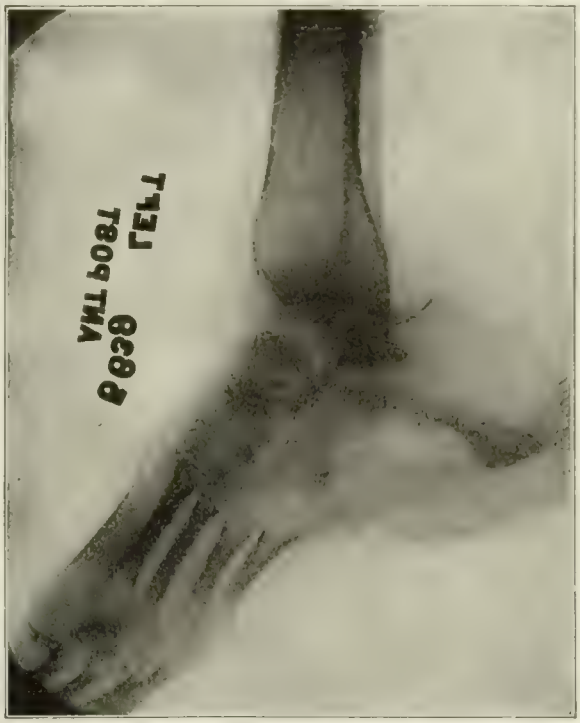


Fig. 2493.—Showing a Later Result of the Operation Illustrating the Imitations of Dorsal Flexion by Contact of the Tarsus with the Tibia

The details of the treatment as applied to a typical case of calcaneovalgus are as follows:

The line of incision begins at a point about an inch above the extremity of the external malleolus midway between it and the tendo Achillis, and is continued downward and forward about three-quarters of an inch below the malleolus over the dorsum of the foot to the external surface of the head of the astragalus.

The sheaths of the peronei tendons are opened and the tendons are cut below the malleolus and drawn backward. The bands of the external lateral and interosseous ligaments are divided and the head of the astragalus is freed from its attachments to the tibia and scaphoid. An elevator is then inserted

between it and the os calcis, and the foot being forcibly inverted, the head of the astragalus is drawn from the wound, and, the attachments on its inner and posterior borders having been cut or broken, it is removed.

One, then, prepares the new articulations. A thin section of bone is cut from the adjoining surfaces of the cuboid and os calcis. On its inner side a knife is passed about the internal border of the scaphoid and the ligament is separated by an elevator. The foot is then displaced outward and the malleoli are laid bare by dissection from their ligamentous attachments and are reshaped somewhat on their internal surfaces to fit the new articulations. The peronei tendons, freed from the lower extremity of the fibula, are passed through a slit at the base of the tendo Achillis, sewn firmly to it, and then drawn forward and reunited to their distal extremities.

The foot is now displaced backward, the external malleolus overlapping the calcaneocuboid articulation, the internal the navicular. The wound is then closed with catgut sutures and the foot is fixed by a plaster splint in an attitude of moderate plantar flexion and abduction.

In the routine of hospital practice the operation is performed under the Esmarch bandage. The tendons are sutured with Lange silk. The wound, having been cleansed with warm saline solution, is closed without drainage. The foot and limb are bandaged with sterilized sheet wadding, over which a light plaster is applied, holding the foot in the attitude described, and the leg at a right angle to the thigh. The limb is afterward suspended between tapes running from the head to the foot of the bed. Great care is taken to avoid constriction. To this, and to the rest assured by the plaster splint, and to suspension, is ascribed the very slight discomfort following the operation, and the absence of complications.

At the end of about three weeks the first support is removed, and the walking plaster splint is substituted, extending to the knee, and fixing the foot in the same attitude of moderate equinovalgus, the sole being equalized by the incorporation of a wedge of cork. The patient is encouraged to walk with equal steps, and to bear weight on the forward part of the foot. At the end of from four to six months the new joint will have become stable, and the fixed support may be discarded for a shoe arranged with a cork wedge beneath the heel, of sufficient thickness; it is compensated for slight equinus, and if necessary the outer border of the sole is thickened somewhat to prevent a tendency to inversion.

Even in the cases in which after-treatment has been neglected, the nutrition of the limb and the appearance of the foot improve with the gain in functional ability, and some of the patients walk so well as almost to merit the term "cure," as applied to cases of this class.

Acquired Calcaneovalgus and Calcaneovarus.—In many cases the foot deformed as a result of paralysis of the calf muscle is in addition turned in a lateral direction, so that the weight of the body falls to the inner or outer side of its center.

Calcaneovalgus, in which the foot is turned outward and upward so that the patient walks on the inner side of the heel, or even on the inner ankle, is not uncommon; the opposite deformity is far less so. Calcaneovalgus is usually a result of more extensive paralysis than simple calcaneus. For example, all the muscles about the foot may be disabled except the peronei, or in cases of a milder type the tibialis anticus may be the only muscle of the front of the foot that is paralyzed.

Calcaneovarus is a much less serious affection, since the foot may be more easily supported. A brace such as is used in the treatment of ordinary varus, without motion at the ankle or provided with a reverse stop, is ordinarily employed. The principles of treatment have been described already. The brace should be employed until it is evident that there is no further tendency toward recovery, when the operative treatment already described is indicated.

Acquired Talipes Equinovarus.—Talipes equinovarus is the most common of the paralytic deformities of the foot. The tendency of simple equinus is usually toward varus, because in plantar flexion the foot is slightly adducted, and because the outer side of the foot is shorter than the inner side, so that in walking with the foot extended the tendency of the foot is to turn somewhat inward. Equinovarus is usually preceded by equinus and the etiology of the one will serve for the other.

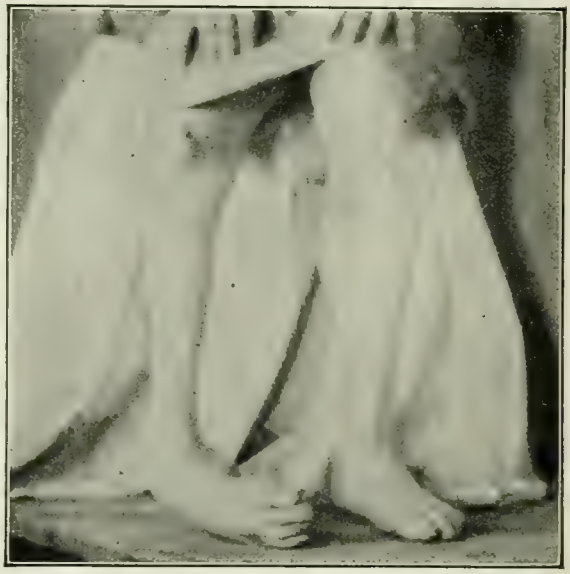


Fig. 2494.—Paralytic Deformity of the Foot, of the Varus Type. The atrophy and shortening of the limb are evident.

In certain cases the varus is more marked than the equinus, as, for example, when the abductors of the foot are paralyzed while the adductors retain their power; or in cases of direct injury as in fracture at the ankle; or when the growth of the tibia has been arrested as the result of injury or disease.

The appearance and effect of the deformity are sufficiently indicated in the description of the congenital form.

Treatment.—If the distortion is recent and therefore non-resistant, the treatment consists in supporting the part in proper position by a brace, of which the Taylor club-foot apparatus is the type. During the night the overcorrected attitude may be assured by a strap running from the upright to the sole plate. Massage, electrical stimulation, and the like may be applied as in the routine treatment of anterior poliomyelitis.

If the deformity is fixed it should be reduced and overcorrected by forcible manipulation under anesthesia. Division of the resistant parts is less often necessary than in the congenital form, but should be performed in suitable cases. The overcorrected position should be retained until time has been allowed for the recontraction of the lengthened tissues, preferably for several months; such rest in the overcorrected position is by far the most effective treatment that can be applied to a weak or paralyzed part.

Astragalectomy and cuneiform osteotomy are rarely indicated, but the latter operation is sometimes of service in checking the tendency toward recurrence

of deformity which is more marked after overcorrection in the paralytic than in the congenital talipes.

Acquired Talipes Equinovalgus.—Simple equinovalgus is usually the result of primary paralysis of the tibialis anticus, the most powerful of the dorsal flexors; thus the foot is drawn somewhat outward in dorsal flexion, while the metatarsal bone of the great toe, having lost the support of the tibialis anticus muscles, falls downward and is drawn outward by the peroneus longus. In this type one's attention is often attracted by the peculiar appearance of the great toe which is deformed somewhat like a hammer toe by the overaction of the flexor longus pollicis in its attempt to take the place of the tibialis anticus. The equinus is usually slight and is secondary to the valgus. If the tibialis posticus is paralyzed in addition, the lateral displacement of the foot is more marked.

Treatment may be begun by placing the foot in a plaster bandage in an attitude of varus and allowing the patient to walk upon it until the tendency toward deformity has been overcome. A support with the catch, as for toe-drop, is applied to the shoe while the tendency toward valgus is checked by raising the inner border of the sole or by the use of a sole plate, as in the treatment of the simple weak foot.

Acquired simple talipes valgus, from paralysis of the tibialis anticus and posticus, is rare. Talipes valgus, when the foot is dislocated outward in cases of complete paralysis of all its muscles, may be regarded as a variety of dangle foot.

Talipes valgus, sometimes called spurious valgus, the simple weak or flat foot, has been described in the preceding article.

Traumatic valgus and equinovalgus, due to fracture at the ankle (Pott's fracture), may be treated by osteotomy of the tibia above the ankle in order that the proper relation of the leg to the foot may be restored. Equinovalgus of slight degree is not uncommon after tuberculous or rheumatic disease at the ankle or at the astragaloscaphoid joints. This is practically one variety of the weak foot.

Talipes from Other Causes.—Talipes caused by cerebral disease or injury, whether of the paraplegic or hemiplegic type, is almost always in the form of equinovarus. The hemiplegic form of talipes is usually more unyielding and rigid than the paraplegic type.

The deformity must be corrected by the ordinary methods. In many instances, when the contractions are not marked, the after-treatment by a brace is not necessary.

Hysterical equinovarus or other forms of deformity are not especially uncommon. The diagnosis can be made by the other symptoms of hysteria, from the history of the onset and duration of the distortion, and from the appearance of the deformity which is evidently merely an assumed posture.

Tendon Transplantation for the Relief of Paralytic Talipes.—When one or more of the muscles are paralyzed the unbalanced action of those that remain tends to distort the foot. The object of tendon grafting or muscle transplantation is to utilize the power that remains by giving an active muscle a new point of attachment where it may be of service instead of an agent of deformity.

Tendon grafting is, as the name implies, the operation of attaching the tendon of a living to that of a paralyzed muscle. The first operation was performed by Nicoladoni in 1882 for the relief of paralytic calcaneus (*Archiv f. klin. Chir.*, 3, 27, S. 660, 1882). The tendons of the peroneus longus and brevis were divided behind the external malleolus, and the proximal ends united to the distal extremity of the divided tendo Achillis.

The first operation on the front of the foot was performed by Parish of New York (*New York Med. Jour.*, October 8, 1892) for the relief of paralytic valgus, by attaching the tendon of the extensor proprius hallucis to that of the paralyzed tibialis anticus, without division of either tendon.

Lange has modified the original procedure by attaching the tendon of the transplanted muscle directly to the periosteum at the point of greatest mechanical advantage (*Munch. med. Wochens.*, No. 15, 1900). In order to carry out this principle, the muscle itself may be partly detached from its origin and its tendon may be supplemented with thick strands of silk in order to assure the attachment at the proper point.

Tendon transplantation is a palliative rather than a curative operation. Its object is to prevent deformity rather than to restore the lost function. It may be combined with other operations that assure security, as with astragalectomy and backward displacement of the foot, a procedure primarily indicated for calcaneus but often of value for other distortions; or with arthrodesis at minor articulations or with cuneiform resections for the purpose of restoring symmetry.

As an independent operation the range is limited as regards the foot. Its chief value being to restore balance disturbed by paralysis of one of the minor muscles.

The operation is not indicated until sufficient time has elapsed to assure the permanence of the disability, and complete overcorrection of existing deformity should if practicable precede the operation by several weeks, in order that the character of the operation may be more accurately determined.

The relative strength of the muscles should be considered in selecting grafts, as well as in making a prognosis. According to Fick it is as follows in kilogrammeters:

Back of the Leg.	
The calf muscle—gastrocnemius and soleus	8.21
Tibialis posticus	0.40
Peroneus longus	0.44
Flexor com. digitorum	0.38
Flexor longus hallucis	0.82
Total	10.24

Front of the Leg	
Tibialis anticus	1.61
Extensor proprius hallucis	0.39
Extensor longus digitorum	0.72
Peroneus brevis	0.31
Peroneus tertius	0.20
Total	3.23

The importance of the calf muscle on the back, and of the tibialis anticus on the front of the leg, is apparent. The former is nearly four times as strong as the other muscles of the combined posterior group, the latter being equal to all the others on the front of the leg.

It is evident therefore that one cannot supply the function of a powerful muscle by a weak one as, for example, in the original operation of Nicoladoni. One muscle cannot perform two opposed functions at the same time, nor can a muscle be transformed from a plantar to a dorsal flexor with any reasonable prospect of success. On the other hand, abductors may be transformed to adductors or *vice versa* and the direction of the plantar and dorsal flexors may be changed with advantage.

The most common form of paralytic talipes is equinovalgus due to paralysis of the tibialis anticus. The most direct transplantation is that of the proprius hallucis. This is divided and the proximal end is sewed to the periosteum of the scaphoid. In most instances the tendon of the paralyzed tibialis anticus is overlapped and shortened to aid in holding the foot in the desired position.

A more effective procedure is to turn back a flap,

from the thick ligament covering the astragalos caphoid articulation and to remove the cartilage from the adjoining bones with the aim of checking the tendency to valgus. The tendon of the proprius hallucis is sewed directly to this flap which is then replaced.

The tendon of the peroneus longus may be utilized also for the same purpose. It is divided through an incision over the cuboid bone. The belly of the muscle is then exposed by an incision on the middle of the fibula. The tendon is then drawn upward and, the muscular attachment having been separated from the lower third of the fibula, the tendon and part of the muscular belly are drawn directly across the leg through an incision over the crest of the tibia and, a channel having been made beneath the skin, the tendon is carried downward to the attachment already described. The peroneus brevis may be transplanted for the same purpose but its action is less effective.

If the peronei muscles are paralyzed the foot turns inward into varus. The proprius hallucis may be utilized as an abductor or the tendon of the tibialis anticus may be split, the outer half being inserted in the neighborhood of the attachment of the peroneus brevis. As aids in holding the foot in position the tendons of the paralyzed peronei tendons may be used as stays; the cut tendons being drawn upward sufficiently to hold the foot in abduction are then embedded in grooves cut in the fibula and covered with periosteum to which they are firmly attached with silk, as suggested by Gallie.

If the varus deformity is well marked a wedge of bone may be removed from the outer and upper part of the foot sufficient to permit overcorrection as an aid to tendon transplantation.

Other operations may suggest themselves in special cases. Operations of the same type are indicated in paralysis of muscles of the posterior group, for the correction of valgus or varus. If the calf muscle is paralyzed the only effective operation is removal of the astragalus and backward displacement in the manner already described under calcaneus.

The operation of tendon transplantation is usually performed under the Esmarch bandages. The attachments are made with strong silk. The foot is then overcorrected and fixed in plaster and it should be used in this overcorrected attitude for many weeks to impress the new position and function upon the patient. Afterward the part should be protected from deformity until it is assured that stability is assured. In other words the operation should be looked on rather as an accessory than as a treatment complete in itself.

Arthrodesis.—Arthrodesis for the purpose of producing ankylosis was introduced by Albert of Vienna in 1878.

Its field is limited in cases of partial paralysis to special joints, in which one aims to check lateral mobility as an aid to tendon transplantation as already described. If all the muscles are paralyzed the aim is to fix the foot at a right angle with the leg and thus to enable the patient to dispense with a brace. For this purpose the ankle, mediotarsal, and subastragaloid joints must be included in the operation. It consists essentially in removing the cartilage from the adjoining bones and nailing or sewing them to one another or assuring contact by a plaster bandage. The operation is not successful unless ossification is well advanced, as in later childhood, which still further limits its field of usefulness.

Royal Whitman.

Foot-and-Mouth Disease.—This disease is also known as epizootic aphtha, aphthous fever, infectious aphtha, aphthæ epizooticæ; Maul-und-Klauenseuche, Aphthenseuche, Maulfäule, by the Germans; as Fièvre aphtheuse, Cocotte, by the French; and as afta epizootica, febbre aftosa, by the Italians.

Foot-and-mouth disease is an acute, highly infectious, febrile disease characterized by a vesicular eruption on the skin and mucous membranes, especially in the mouth and in the interdigital spaces.

Similar to other animal plagues, this disease invaded Europe in the east and with every war involving western and central Europe. Its contagious nature was recognized as early as 1764, but until the middle of the last century was usually associated with various atmospheric and climatic influences or attributed to spoiled feed. The infectious character of this disease was recognized by Bollinger and since that time it has been generally supposed to be caused by specific infection, although the etiology is not yet definitely established. Various investigators attributed the disease to bacteria or protozoa, but Löffler and Frosch (1897–1900) succeeded in definitely proving that the contagion passes through porcelain filters and that it should therefore be classed among the filterable microorganisms.

Klein, Schottelius, and Kurth have described coccus-like bodies as the causative agent of the disease, while Terni attributes the disease to protozoa (*Cytoryctes jenneri*). More recently Siegel connects with the etiology of the disease cocci of 0.1 to 0.2 microns in size (*Cytoryctes cocci*), which he found in the blood of affected animals, also in the vesicles, in the plasma of the cells and in the heart muscle of the affected cattle. These findings have been substantiated by Nicolaus and Betegh, and others.

The contents of the vesicles is most contagious, while the blood contains the infection in a diluted condition and only at the beginning of the fever.

The saliva, nasal discharge and other secretions become infectious only after contamination from the contents of the vesicles. At the onset of the healing process the infection disappears, and animals after a sickness of ten days can no longer infect.

The disease has occurred in Europe at periodic intervals when it usually spreads through the entire continent not sparing any of the countries and after raging from two to four years it usually subsides, being followed by a period of absence of the disease for several years, after which time it again commences to spread. During the outbreaks in the various countries of Europe the larger proportion of the cloven-footed animals usually became affected, and the measures which were adopted for its suppression or control were found unsatisfactory in checking its spread, thus Germany, France, Great Britain, The Netherlands, Austro-Hungary, Russia, and other countries suffered great losses from the appearance of the disease at different times.

According to statistics collected by the German Empire in 1890, 431,235 head of cattle, 230,868 sheep, and 153,808 swine were affected with the disease. It is claimed that the losses from this disease in England in 1883 were $5,000,000.

The disease reached America through an importation of cattle from England through Montreal in 1870, when it spread over the various provinces in Canada, the New England states, New York, and New Jersey. This outbreak was effectively controlled and the spreading of the disease prevented. Excepting other minor outbreaks which occurred in this country from other importations of stock, the outbreak of 1902 threatened the greatest danger, but with proper quarantine measures and destruction of all infected and exposed herds, the disease was controlled and limited to four of the New England states.

The last outbreak which occurred in the United States and which was traced to contaminated vaccine lymph from Japan occurred in 1908. This outbreak was also checked with proper measures, and as the disease was found to have spread over a considerably wide area (Michigan, Pennsylvania, New York, and Maryland) before cognizance was taken of its existence, it required heroic work on the part of the

officers of the Bureau of Animal Industry in controlling and eradicating this outbreak. Since that time this country has been free from the disease and with the quarantine prescribed by law for imported animals and the present requirements of testing all importations of vaccine lymph for possible contaminations of foot-and-mouth disease there appears to be little danger of the introduction of the disease into this country.

The losses sustained from foot-and-mouth disease were in most outbreaks only small, from one to two per cent. of the affected animals dying as a result of the disease, although there have been outbreaks at times known as the malignant form of the disease when the mortality was much greater and it has not been uncommon to observe losses up to thirty per cent. and higher. The losses which were sustained in outbreaks of foot-and-mouth disease were not the direct result of fatalities, but due to the fact that all classes of animals on the farm are susceptible and therefore the indirect losses are much greater than in other infectious diseases. Cattle are most susceptible, next in order are hogs and sheep. Dogs, cats, goats are only occasionally attacked. Reindeer, deer, buffaloes, yaks, camels, antelopes are also said to be susceptible.

The infection is not air-borne and the transmission takes place from animal to animal, either by licking or from contact with contagion through carriers. These of course may be of the most varied kind, attendants, stable utensils, contaminated feed, roads over which diseased cattle have been driven, dogs, birds, and all other means by which the contagion is carried from place to place. Sucking calves are usually infected from the udder or milk from cows suffering from the disease.

An attack of the disease does not confer permanent immunity. Observations seem to indicate that the immunity afforded the animals varies between six months and one or two years. Not infrequently, however, cases have been observed in which the reinfection of the same animal has occurred within three months. It is claimed that the appreciable diminishing of the disease after widespread outbreaks is due to the fact that the cattle have in many instances acquired immunity for a more or less protracted period.

Symptoms.—The time of incubation in the natural form of the infection is usually from three to seven days. At the onset of the disease there is usually a high fever, which may reach 106°; this, however, subsides after one or two days, as soon as the vesicles develop. The lesions in the mouth are most frequent in cattle, and in other susceptible animals as sheep, goats, and hogs they are less frequent. At the onset of the disease there is a diminished appetite, the animals chewing their food very cautiously on account of the pain in the buccal mucous membrane. The mouth is usually kept closed and from time to time they open it with a smacking sound, later the taking of food entirely ceases. The saliva drops in strings from the commissures of the lips, and the animals enjoy keeping their heads in a pail of water placed before them.

From the second and third days on the inner surface of the lips, on the tongue, and other parts of the mucous membrane of the mouth vesicles appear which may vary in size from a pea to that of a walnut. The vesicles may extend to the muzzle and backward into the pharynx and soon burst leaving an exposed red surface. The salivation becomes more profuse, and there is very active movement of the tongue. The denuded area following the bursting of the vesicles soon becomes covered with new epithelia and the healing process is ordinarily concluded in five to seven days.

The lesions on the feet are first indicated by lameness. Examination in such cases reveals a reddening and heat of the skin above the horny part. In from one to two days vesicles appear which rapidly increase in size, and at first are filled with a clear, later with cloudy fluid. They burst and the healing process is much slower in this part than in the lesions of the mouth. The lesions of the udder occur usually simultaneously with those of the mouth, the vesicles appearing upon the teats at times reaching the size of a hazelnut. The udder in more severe cases is swollen, and immediately surrounding the vesicles it is reddened and painful. The vesicles are usually ruptured in the course of milking, and provided the healing process is not delayed by the mechanical irritation of milking the healing takes place in from five to six days.

Complications.—The course of the disease described above is that of normal cases; frequently, however, complications set in. The lesions in the mouth may extend into the gastrointestinal tract, involving these parts and causing a severe disturbance in the digestive process, which frequently results in a fatal termination. Such conditions occur quite frequently in young animals. The lesions in the mouth may also lead to a more intense pathological process, infections with secondary organisms may bring about deep necrotic ulcerations and consequent conditions which require a longer time for repair. The affected digits are especially liable to secondary infections, and due to this fact it is not at all infrequent to observe suppurations resulting from outside infections which may infect the deeper structures resulting in losing of the hoofs.

The extension of the lesions in the udder may cause severe inflammatory conditions of that gland with known serious consequences such as the various forms of mastitis.

Diagnosis.—The diagnosis of the disease is not difficult, especially since the highly infectious character of the disease with the mentioned lesions is typical only with foot-and-mouth disease. The occurrence of sporadic cases, however, may cause difficulty. Of the conditions which may be mistaken for foot-and-mouth disease, traumatic injuries of the mucous membrane may be mentioned, Stomatitis vesiculosa of cattle, Stomatitis ulcerosa of hogs, Stomatitis aphthosa of calves and lambs, and actinomycotic affections of the dorsum of the tongue, besides the various forms of mycotic stomatitis. The differentiation of these conditions from foot-and-mouth disease may be readily made when the symptoms, course, and the infectious character of the disease are considered.

Treatment.—In the early stages of the disease on account of the pain in the mouth the animals are unable to take up rough food, and they should be given gruel and mashes. The buccal cavity should be kept clean by frequent washing with either ordinary salt solution, or astrigents containing antiseptics, as alum, copper sulphate, potassium chlorate, boracic acid, lysol, etc. The lesions should likewise be treated with antiseptic washes, or astringent antiseptic powders may be used for covering the affected parts.

In the presence of an affection in the udder the milk should be regularly taken, if necessary by the introduction of milk tubes. The udder should be washed with a mild antiseptic solution. In the presence of intense inflammation and loss of substance of the udder, it should be washed carefully and treated with antiseptic ointments. In a severe parenchymatous inflammation of the udder, the rubbing of the organ with a ten per cent. ointment of iodine or camphor ointment (1 to 4) is beneficial. Complications which may result from the affections, such as deep-seated abscess formations, etc., should be treated in accordance with the principles of surgery.

In the control of the disease where it was impossible

to check its spread, artificial infections were often resorted to by which the infection of all animals in the stable was hastened and all animals recovered within a short time. This method is still in practice in most of the European countries, but in more recent times it proved of an advantage in the early outbreaks to adopt more stringent measures in destroying all animals of the affected herd and often those which had been exposed to the infection. With this practice, the two last outbreaks of the disease in the United States have been successfully combated. It consists in the rigid quarantine of infected premises and in slaughtering the diseased and exposed animals at the earliest possible moment, and in thoroughly disinfecting the stables and the contents of the buildings in which they have been sheltered.

The disease is transmitted to man principally by the drinking of milk of affected animals, and through the act of milking, directly to the attendants whose hands become infected. In such instances it occurs through the virus coming in contact with wounds and other abrasions. In human beings the manifestations of the disease are also most frequent on the fingers, the arches of the nails, in the mouth and throat; constitutional symptoms, fever, gastric disturbances, diarrhea are frequently associated with the disease.

The disease in man usually runs a favorable course, although in many instances where it effects children it may result fatally, either directly from the affection or as the result of other complications.

The milk from affected animals should not be used for human consumption unless it is boiled, which procedure destroys the virus. Attendants should be careful in the handling of affected animals in order to avoid an infection. ADOLPH EICHHORN.

Forceps, Obstetrical.—It is probable that no mechanical apparatus which was ever constructed has rendered half the service and benefits to the human race which has been rendered by the obstetrical forceps. We all come into the world practically in the same way, through the passage in the maternal generative organs which are enclosed within the maternal pelvis.

Parturition is the most natural thing in the world and when the conditions which surround it are natural, midwives and obstetricians are superfluous and may be regarded in the light of luxuries. But there is no physiological function of which there are no deviations from the normal. Man and animal are occasionally in a hopeless situation with regard to the function of parturition, and it then becomes simply impossible of accomplishment without the assistance of art and human intelligence. Hence arose the necessity for some sort of a contrivance which should serve as an extension of the hands of the midwife, which should grasp and extract the living being which was struggling to get into the world, and which would do it without killing or maiming it.

Midwifery is an art which is so ancient that it seems incredible that those who devoted their time, their thought, and their observation to it in the ages before the dawn of history should not have found some expedient of a mechanical character to help women who were unable to deliver themselves. People were not all fools in prehistoric times and the logical process of reasoning, of deduction from observation, and of drawing valid conclusions must have resided with some of those who practised midwifery. But if they made use of any mechanical apparatus tradition did not hand down any account of it to those who began to write history, and so we have nothing but our imagination to fall back upon in regard to their operative obstetrics.

The book of Genesis antedates the father of medical history by many centuries. From this book we learn of the death of Rachel "in hard labor." "And Rachel travailed and she had hard labor. And it came to pass that when she was in hard labor the midwife said unto her, Fear not, thou shalt have this son also. And it came to pass as her soul was departing (for she died) that she called his name Ben-oni, but his father called him Benjamin." (Gen. xxxv., 16, 17, 18.)

In the book of Exodus we also have a picture of midwifery practice in Egypt and a statement that Hebrew women were delivered more readily by the midwives than Egyptian women. "And the King of Egypt called for the midwives and said unto them, Why have ye done this thing, and have saved the men children alive? And the midwives said unto Pharaoh, Because the Hebrew women are not as the Egyptian women, for they are lively and are delivered ere the midwives come in unto them." (Ex. i. 18, 19.) Again the imagination fills in the gap and pictures the hard labors which fell to the lot of some of the Egyptians, with no record as to the means by which they were delivered.

Hippocrates, who is usually regarded as the father of scientific medicine, using the term in its broadest sense and differentiating it particularly from the so-called medical practice of priests and conjurers, was a keen observer, a philosophic thinker, and a very voluminous writer. Among his many contributions to theoretical and practical medicine there were observations relating to obstetrics, but in none of them do we find any intimation that he was in the habit of using any other instrument than his hands for the assistance of parturient women, and these he used in prolonged labors, for traction, when the head of the fetus was small. (An exception should be made in regard to the crotchet which was described by Hippocrates, by Aetius, and by all other ancient writers on midwifery, but was used only when the child was dead or its life was despaired of.)

The Arabians in the tenth and eleventh centuries kept the lamp of medicine burning when it was dim or had gone out among other nations, and we find in their writings the record of the use of forceps in labors which were difficult. But the forceps of Albucasis and Avicenna were properly cranioclasts with three or four blades and teeth, for grasping the fetal head, on the inner surface of the blades. They were destructive instruments and were evidently employed only when the fetus was dead or when it could not be delivered alive.

Rueff (1554) used a long smooth-jointed lithotomy forceps for the extraction of dead fetuses. He also used a duck-bill forceps and a toothed forceps. A three-bladed duck-bill lithotomy forceps was employed about the same time by Pierre Franco and by Heister under similar indications, in preference to hooks which had previously been used. In other words, the principle of traction for the delivery of the fetus had probably been recognized for many centuries.

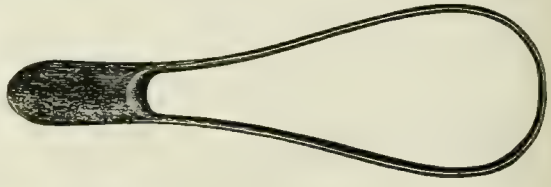


FIG. 2495.—Whalebone Fillet.

Even more ancient than these destructive instruments is the fillet which according to Leishman is the most ancient of all obstetrical instruments which have been used to extract a living child. In its simplest form it was a loop of whalebone which was to be adjusted over the head of the fetus and used as an instrument of traction. Of course its adjustment

was frequently difficult or impossible, and it could be applied only when the head was low in the pelvis. It was extensively used by the Japanese, who added to it a silk net which was drawn over the fetal head, probably as a means of protection, before traction was begun. Ramsbotham describes it as being made of a strip of strong cloth, silk, or leather in the form of a noose, sewed at the side and opened at the ends to admit a piece of whalebone, cane, or wire throughout its entire length. After it had been adjusted over the head the whalebone was withdrawn, the loop tightened and extraction performed by main force. The use of such an instrument upon the cranium was of course very ineffective, though it might have been serviceable in breech presentations. At any rate it has fallen into disuse, in this country at least, and in a practice extending over thirty years the writer has never had occasion to use it, nor has he known of its use by others. It was advocated in England by no less an authority than Smellie (1779) who engaged it between the occiput and the chin, though we fail to see how it could be thus used with efficiency or mechanical advantage. The vectis or lever is the offspring of the forceps. It is said that Roonhuysen of Amsterdam purchased the secret of the forceps from Hugh Chamberlen at the end of the seventeenth century and that when he in turn was supposed to have sold the secret to others he deceitfully sold the vectis and not the Chamberlen forceps.

Leishman states that many successful deliveries were accomplished with the vectis by Roonhuysen, by his son, by Ruysch, by Visscher, by Van den Poll and by others who obtained the secret. Visscher and Van den Poll are said to have paid 5,000 pounds for the secret in 1753 in order to give it freely to the world.

The original vectis was merely a flat piece of iron curved at either end and covered with leather to

Fig. 2496.—The Vectis.

protect the tissues of the patient. As it is now used, though it is used but seldom since it will do nothing which cannot be done better with the forceps, it is merely a single blade of a straight forceps. The lever action is sometimes useful, especially when the head is low in the pelvis, and it may be used to complete the rotation of the head, but it can have little value for traction purposes, however much the blade may be curved; so that it is in every way inferior to the forceps. Besides, no matter how carefully it may be used it is a greater menace to the soft parts of the mother than the forceps.

It is hardly necessary to say much about the blunt hook and the crotchet, both of them very ancient but destructive instruments, and the precursors of the forceps.

Fig. 2497.—The Blunt Hook.

The blunt hook is, of course, useful almost solely in breech presentations and when the child is already dead. It is not impossible to extract a living child presenting at the breech by applying the blunt hook over the groin and even the fillet may be used for that purpose, especially when two fingers of one hand are also placed in the groin as a guide and a protection. But the procedure is not a desirable one, it is dangerous alike to mother and child, and fortunately is seldom resorted to. In the extraction of a dead child after craniotomy or embryulcia the blunt hook may serve as an efficient tractor by inserting it into the flexure of a presenting joint, due care being always exercised to protect the maternal tissues.

The crotchet is a sharpened hook which is designed for fixation into the tissues. It is practically of no

Fig. 2498.—The Crotchet.

use when fixed in soft tissues and must have the resistance of a joint or a bone to make it of any value as an instrument of traction. It is a barbarous instrument, even in its guarded form, and happily it is obsolete. If destructive midwifery becomes necessary, especially at the cranial end, the cranioclast or basiotribe will sufficiently reduce the size of the head to permit of its extraction without resort to these ancient and clumsy devices.

It is a relief to turn from destructive instruments and processes to the mild and humane and conservative measures which are associated with the notion of the obstetric forceps.

Schroeder is quoted by De Lee (Principles and Practice of Obstetrics) as saying that the coming of

Fig. 2499.—The Guarded Crotchet.

the forceps was delayed because in past ages men were not allowed to attend confinements except in cases of great difficulty, their presence meaning the death of the child and the possible mutilation of the mother. The appearance of a man-midwife in the lying-in chamber was therefore always a source of dread to the woman and often her death-knell.

Midwifery was also regarded as a woman's business rather than a man's, and hence it was long before it assumed the dignity which properly belongs to it as, in many respects, the most important art in which a human being can be engaged. We who are participating in its latter-day glories and perfections can realize but imperfectly the vicissitudes through which it has passed in reaching its present honorable estate.

The discovery of the obstetric forceps is now universally attributed to the Chamberlen family and probably to Peter Chamberlen the elder, at the very beginning of the seventeenth century. Aveling's monograph, "The Chamberlens," published in 1882, has given a detailed account of the history of the five generations of this remarkable family, and all the salient facts which have been discovered in connection with their relation to their forceps. The discovery was such a momentous one that a few statements concerning the family should not be inappropriate.

William Chamberlen, a Huguenot refugee, left Paris and came to Southampton in England in 1572 with his family. He afterward went to London and died previous to 1596. He was in no way connected with the discovery of the forceps. His son, Peter Chamberlen the elder, was licensed by the Barber Surgeons Company prior to 1598 and was apparently in good practice in 1607. Between 1598 and 1607 he probably invented the forceps. In 1612 he was jailed at Newgate for practising *physick*, but was released at the mandate of Anne, the Queen of James I., and the Archbishop of Canterbury. He had probably at-

tended the Queen in her confinements and in 1614 she gave him forty pounds and a diamond ring. He was also surgeon to Henrietta, Queen of Charles I., and attended her in a miscarriage in 1628.

Peter Chamberlen the second was born February 18, 1572, was licensed by the Barber Surgeons Company in 1596 and was frequently fined by the College of Physicians for working outside the province of surgery. In an ineffectual effort to have the midwives incorporated in 1616, in order to secure their patronage, he is reported to have said that he and his brothers knew more about obstetrics and obstetrical operations than anybody else. Naturally he was not popular, and his secret method of treatment was not approved.

Peter Chamberlen the third was born in 1601, received his doctor's degree at Padua in 1619, at Oxford in 1620, and at Cambridge in 1621. He became a fellow of the College of Physicians in 1628, and tried, ineffectually, like his father, to have the midwives incorporated in 1634. Subsequently he became very eccentric and erratic like so many others at the time of the English Revolution.

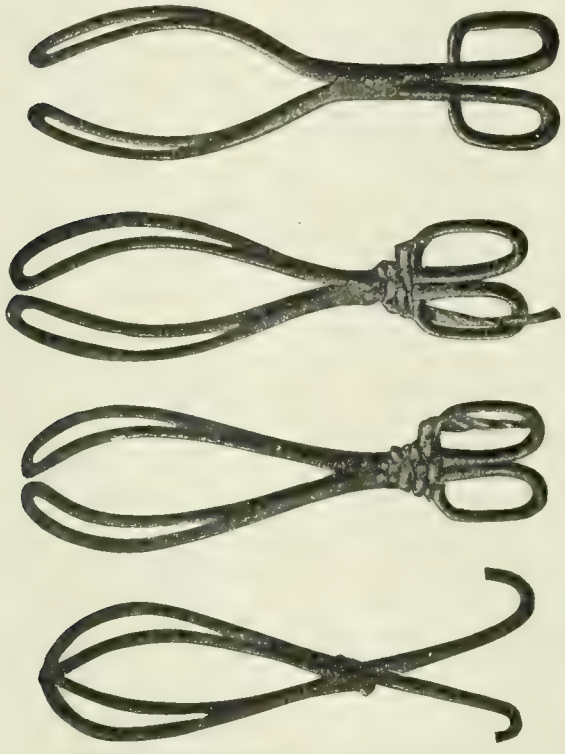


Fig. 2500.—Four Varieties of the Chamberlen Forceps.

Hugh Chamberlen was born in 1630 and became learned and distinguished. He translated Mauriceau's French work on obstetrics into English in 1672 and was on very friendly terms with that great French obstetrician. He declared in this translation that he and his brothers delivered women who could not be delivered by others. He was not infallible, however, and on August 19, 1670, was asked by Mauriceau to deliver a woman with a greatly deformed pelvis. After trying for three hours he gave it up in despair, having so injured the woman in his efforts that she died the following day. He was the royal physician in 1673, but this did not prevent his being fined by the College of Physicians in 1685. The secret of the forceps was sold by him to Roonhuysen of Amsterdam, and during the life of his son Hugh, Jr., who was the last of the line, the secret became generally known. In 1733 Giffard and Chapman, who had made improvements upon the Chamberlen forceps, stated that it was a noble instrument and was then well known by all the principal men of the profession both in town and country. Chapman declared further that many women, then living, owed their lives to its use.

In 1813 in a secret closet at Woodham, an estate which had belonged to the Chamberlens prior to 1715, and in connection with coins, medals, etc., four pairs of forceps were found which represented the different stages of the instrument at the time of the death of one of the Peter Chamberlens in 1684. These four forceps are described by Ingraham (*Am. Jour. of Obstetrics*, 1911, p. 846) as follows:

1. One blade 12½ inches long, the other 13. Length of each blade to joint 8 inches. One handle 4 inches long, the other 4½, each ending in a blunt hook. The two portions are united by a nut which can be unscrewed. This is the original type.

2. Length 12 inches, length of blade to joint 9½ inches. Fenestrum 8½ inches long in one, 5½ inches in the other. Width of fenestrum in one ¼ inch, in the other 1⅛ inches. Handles 3¼ inches long, looped for two fingers on one side and the thumb on the other. United by a braided cord through an aperture for a rivet. The two portions can be united or disjointed.

3. Length 12 inches, similar to No. 2 except that the fenestra are equal in dimensions, being 6 inches long and 1 inch wide.

4. Length 13 inches, length of blades to joint 8 inches, length of fenestra 5 inches, breadth 1 inch. Handles 5 inches long, looped, but they may be united by a rivet fixed in one half and fitting loosely in the other. Divergence of apices when the instrument is closed 1¼ inches.

Thus it will be seen that the obstetric forceps of 1684 contained most of the essential features of the forceps of the present day. Its length was sufficient for cases in which the head had engaged, it had the cephalic curve with sufficient interval at the apex to prevent undue pressure, the blades were crossed and could be effectively locked, and the fenestræ were sufficiently large. It lacked the pelvic and perineal curves, the shoulders upon the blades and other minor and relatively unimportant features.

In spite of the facts, therefore, that it was retained as a family secret for a hundred years, and was slightingly referred to by such eminent men as Smellie as a "nostrum," it must be regarded as a great contribution to human efficiency and one which will immortalize its inventor as a benefactor of the human race.

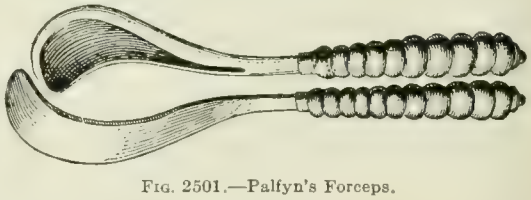


Fig. 2501.—Palfyn's Forceps.

After all, the policy of the Chamberlens in endeavoring to retain for their own advantage the benefits of their invention did not differ from that of inventors of useful appliances now-a-days and should not subject them to the obloquy which many writers have been disposed to inflict upon them. Furthermore, as Aveling justly remarks, they lived at a time when secrecy and mystery in the private affairs of men were more general and were considered less reprehensible than is the case at the present time. When we realize the eminence of Mauriceau as an obstetrician in France, and the fact that he was a friend of Hugh Chamberlen and permitted him, if he did not ask him, to translate the first volume of his work on

obstetrics in 1672, that he was familiar moreover with the Chamberlen forceps which was superior in every way to the crotchet, the instrument which was used by Mauriceau, it seems very strange that Palfyn of Ghent should have presented his forceps to the Paris Academy of Medicine in 1723 as an entirely new invention.

This instrument was called by him *mains de fer* (iron hands). It consisted of two straight blades with a cephalic curve, the blades neither crossing nor articulating. It is difficult to see how he could have effected delivery with such an instrument in any case which would not have ended just as well without it. De La Motte criticized it unfavorably and though the Chamberlen forceps was quite extensively used in Holland and England, he seemed to be entirely ignorant of it. He stated furthermore that Palfyn's instrument could not be used effectively, which was quite probable, and that if an available instrument for the delivery of women should be invented and kept as a secret the inventor should be treated like Prometheus. Perhaps he was more familiar with the Chamberlen story than those who reported his statement were aware.

The Chamberlen forceps being now before the world the era of improvements and modifications of it began.

Freke published an account of his *extractor* in England in 1734. Gifford in the same year in his "Cases in Midwifery" published the first illustrations of the so-called English forceps. Chapman in 1735 gave a description and a cut of his forceps which is practically

Fig. 2502.—The Levret Forceps.

identical with Chamberlen's. The loose lock and the blunt hook on each handle which were described as innovations had no particular advantages over the Chamberlen instruments.

The English lock with the male and female blades is said to have been invented by Walker, grandson of Peter Chamberlen the third, and a member of the fifth and last generation of the Chamberlen obstetricians.

The English lock, the wooden handles and the pelvic curve have also been attributed to Smellie (1779) and Leishman declares with great positiveness that the credit for the two former certainly belongs to him. He thinks the claim of Smellie to the pelvic curve is doubtful. The opinion at the present time is general that the credit of the pelvic curve belongs to Levret, whose forceps also had the definite addition of the French lock which is a pin or screw or pivot in one blade fitting into a notch or tenon in the other, and thus holding the blades firmly together. In the English lock the male blade at its shank fits securely into a slot or depression in the shank of the female blade. The date of these additions is 1746, and about the same time Dussé crossed the blades and lengthened them. We must not forget, however, that in type 4 of the Chamberlen forceps the blades were crossed, there was a pin or pivot joint, and its length was thirteen inches, so that the only actual addition of importance thus far was the pelvic curve which certainly was an improvement, as it permitted traction in conformity with the central axis of the pelvis.

France added another decided improvement at this same period (1747) in the form of shoulders to the handles which was the contribution of Jean Louis Petit. There are many occasions when this adjunct is not required but in difficult extractions in which there is danger of too much lateral pressure from the handles it is certainly a great advantage to be able to distribute the traction force by placing the fingers of one hand upon these shoulders. Too often this precaution is not observed especially by those who are inexperienced in the use of the forceps.

In 1783 Stein attached a dynamometer to the forceps so that the exact amount of pressure could always be determined.

The perineal curve was the next addition, permitting traction backward without injuring the perineum as the head was drawn backward through the cavity of the pelvis. It was first employed by Pugh in 1754 and then in a more pronounced degree by Johnson in 1769, Sleurs in 1783, and Mulder in 1794. It is discarded in most of the forceps of the present day as unnecessary and superfluous. It is unnecessary in axis traction forceps but the principle must not be forgotten, whatever type is used.

We have already referred to Smellie's contributions of the English lock and the wooden handles, which certainly furnish a much better grip than the thin steel handles. He also devised an instrument eleven

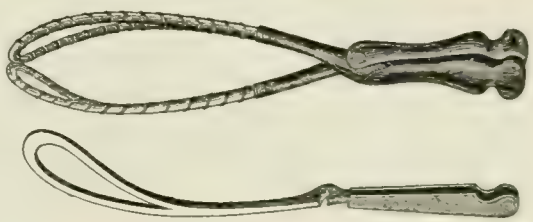


Fig. 2503.—Smellie's Short Forceps.

inches long, seven inches from the lock to the tip of the blades, three inches at the widest portion of the curve, one inch between the tips and without the pelvic curve. This instrument has been a great favorite in this country as a short, straight forceps, and is particularly, almost solely, applicable to cases in which the head is detained at the outlet. It has remained practically unchanged for nearly a hundred and fifty years.

In Germany Busch in 1796 modified the cephalic curve of the Levret forceps so that it would better adapt itself to the fetal head; he also shortened it to thirteen inches. Naegele added shoulders to the handles and Brünninghausen gave it a lock which was a combination of the English and the French. It is the type of the forceps which is in common use in Germany.

Aside from the principle of axis traction in the construction of the forceps, which was first advocated as a distinct principle by the Huberts of Brussels, but with which the name of Tarnier is chiefly associated, the modifications have been of a minor character adapted to the inclinations of an individual, a school or a particular section of country.

In this country during the last century the Philadelphia school of obstetricians was dominant and hence

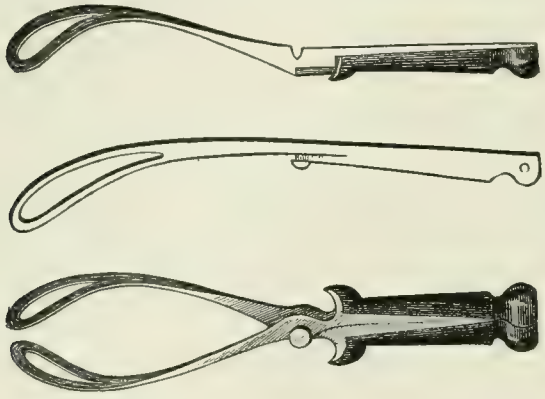


Fig. 2504.—The Naegele Forceps.

we find preference for their forceps, especially those of Hodge, Wallace, and Smith. They are all provided with pelvic and cephalic curves, the latter being quite ample, metallic handles, French lock or some modification of it, and are fifteen or sixteen inches long. They are fairly light in structure, the elements of the shank are parallel and they are well adapted for grasping the head in any portion of the pelvis.

Fig. 2505.—The Hodge Forceps.

In New York the preference among many obstetricians for years has been the Simpson forceps or the Elliot modification. For all around purposes the latter is as good a forceps as was ever made. It is fifteen and a half inches long, two inches longer than the Simpson, nine and a half from the lock to the tip of the blades, seven-eighths of an inch between the tips of the blades, a quarter of an inch less than Simpson's and two and three-quarter inches at the widest part of the cephalic curve, half an inch less

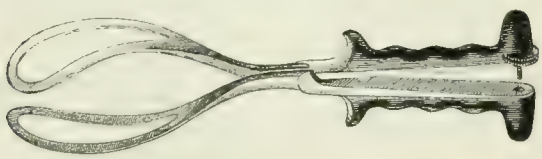


Fig. 2506.—The Elliot Forceps.

than Simpson's. It also has a screw and pin in the end of the handles which can be drawn out as a means of regulating the lateral pressure on the handles when the instrument is in position for use.

At the Sloane Maternity, the obstetric department of the College of Physicians and Surgeons in New York, the McLane forceps with solid blades has been the favorite for many years. So great success has attended its use that it proves that fenestræ in the blades are not essential to successful delivery.

A forceps with very long and narrow blades was devised by the late Isaac E. Taylor for introduction within a cervix not more than one and a half inches in diameter. It was most skillfully used by him but its field is of course a limited one, and it has received very harsh criticism especially by Breus and other German writers on the ground, too sweeping by far, that the uterus never should be entered with forceps when the dilatation of the os uteri is only one and a half inches.

The principle of *axis traction* which has been added to many recent models of the obstetric forceps is a very important one. It is of no particular service when the head is at the outlet, but when it is within the cavity of the pelvis, and particularly when it is above the brim and has not yet engaged, an axis-traction forceps or the application of axis-traction becomes indispensable. Axis traction means pulling in the central axis of the pelvis which is a curve, otherwise known as the curve of Carus.

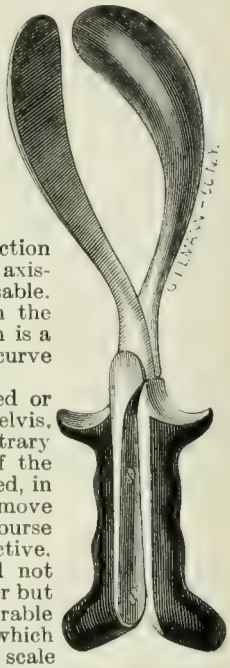


Fig. 2507 —The McLane Forceps.

Before the head has engaged or has reached the bottom of the pelvis, traction forward is exactly contrary to the direction of the axis of the brim, when it is normally inclined, in which direction the fetus must move during delivery if it takes the course which is proper and most effective. Consequently traction forward not only means great waste of power but it means unnatural and undesirable compression of the fetal head, which no doubt frequently turns the scale between life and death.

The name of Tarnier is most conspicuously associated with axis traction and the axis-traction forceps, for he has elucidated the principle as no one else has done before or since his time, and in his essay published in 1875 he demonstrated mathematically the soundness of his position, upon which basis his position is irrefutable. His work is second in importance only to the invention of the obstetric forceps itself as an instrument of traction.

According to Von Siebold (Essai d'une histoire de l'obstétricie, Paris, 1893), Brulatour, in 1817, made the first reference to the application of axis traction to the forceps. He suggested the passing of cords or tapes through the borders of the blades and traction upon them in connection with traction upon the handles. His suggestion does not seem to have excited much attention and was soon forgotten. In 1844 Hermann of Berne constructed an odd-looking

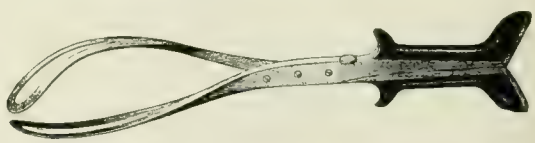


Fig. 2508.—Taylor's Narrow-bladed Forceps.

forceps but based apparently upon correct principles, except that he tried to apply and incorporate in his instrument too many of them. His forceps had a tremendously exaggerated perineal as well as pelvic curve, it had traction rods attached to the blades to pull backward and a traction handle at the shank to pull upward and forward. It was intended for use when the head was at the superior strait but how it could be adjusted is a mystery. It was sent to Stoltz

for his criticism and he very properly remarked that it would be unwise to abandon the simple instrument of Levret for such a complicated one as this. In 1860 Hubert of Louvain grasped the importance of the principle of axis traction and attached a straight bar at the end of the back of the handles of the Levret forceps and at right angles to them. This enabled him to obtain partial axis traction. Subsequently his son transferred the bar, curved instead of straight, to the region of the shank of the forceps and this gave some additional power in axis traction, especially with the head above the superior strait.

In 1871 Moralés made a forceps with a very exaggerated perineal curve which gave him greater power in axis traction than the Huberts had with their's. In 1875 Laroyenne revived the project of Brulatour and passed cords through holes in the middle of the anterior and posterior borders of each blade. This gave him two ends or handles for traction in addition to the handles proper of the instrument. In the same year (1875) Tarnier published his thesis in demonstration of his proposed axis-

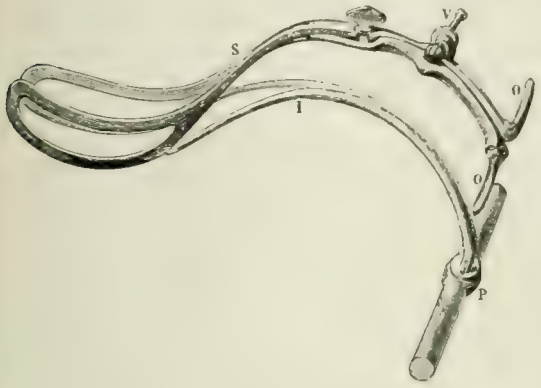


Fig. 2509.—Tarnier's Forceps; early model.

Fig. 2510.—Tarnier's Forceps; late model.

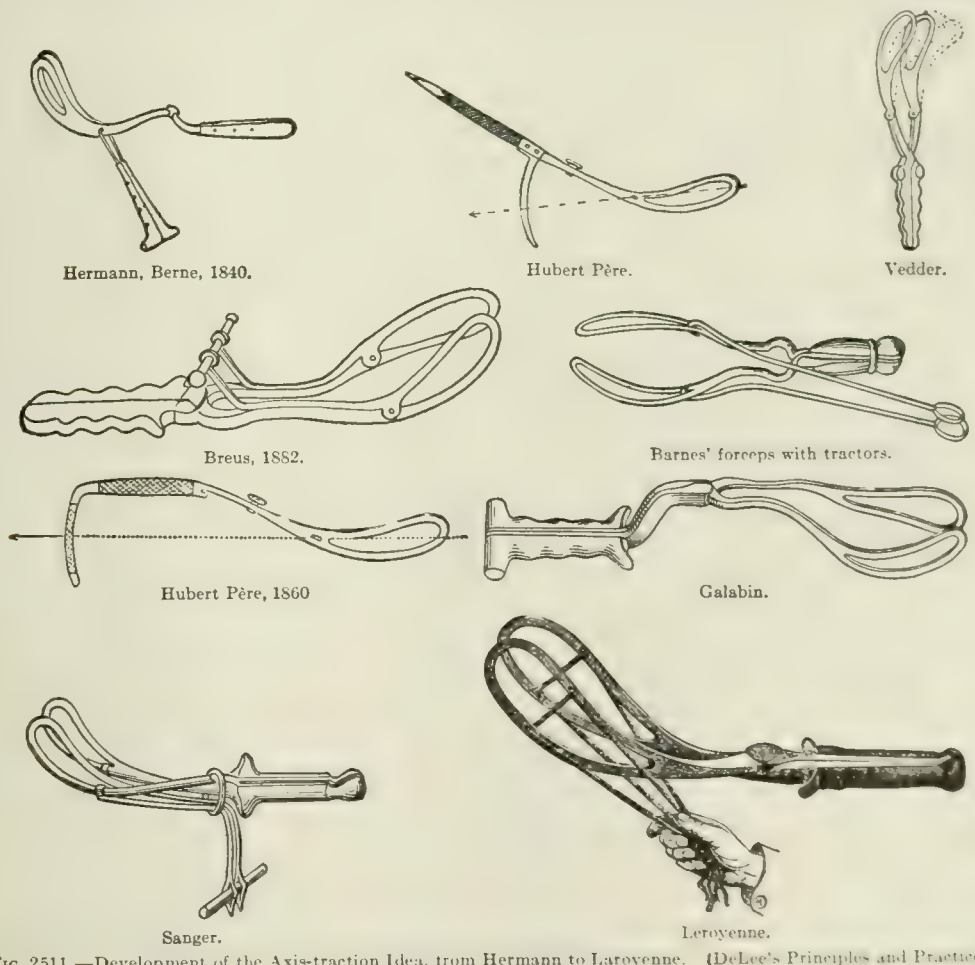


Fig. 2511.—Development of the Axis-traction Idea, from Hermann to Laroyenne. (DeLee's Principles and Practice of Obstetrics, Saunders, 1913.)

traction forceps. He showed mathematically the defects in the instrument of Levret and summarized the advantages of his own in the three following statements: (1) It will pull in the axis of the pelvic curve. (2) It will permit the head to have almost as much mobility as in natural labor. (3) It indicates the direction in which it is proper that the traction should be made. The first model (1877) shows an enormously exaggerated perineal curve both in the handles and in the traction rods which are parallel to each other. It was unsparingly criticised by the obstetric veterans Pajot and Charpentier on account of its complicated structure, its expense and the excessive pressure to the head which it would cause, though Pinard and Budin were astonished at the insignificance of its pressure compared with other instruments, and the slight exercise of strength which was required in using it. It was at once taken up by the obstetricians everywhere as a most important invention and was modified and simplified in various countries. Tarnier himself was reproved in the Paris Academy of Medicine on the ground of its incompleteness and imperfection, and because he had at that time found it necessary to make thirty-four successive models. The various modifications are all in the direction of simplicity, the traction bars and handles being retained.

A. R. Simpson of Edinburgh was the first to modify the Tarnier model, adapting the traction appliances to the Simpson forceps. Lusk of New York modified it at about the same time. Many modifications have been made in other countries. Breus in Germany has

Fig. 2512.—The Breus Forceps.

a model which is much used because of its lightness and the facility with which it can be applied. Poullet in France modified the method of Laroyenne by passing tapes through the lower border of the fenestra. Traction rods and handles devised by Reynolds and others are now available in this country, which can be attached to the fenestra of almost any forceps and the axis-traction principle thus be made easily applicable. From personal experience they seem to be quite as effective as those which are attached to the various forms of axis-traction forceps and the expense of an instrument which is thus equipped is very much less than that of the more elaborate and cumbrous models.

The Purpose of the Forceps.—The purpose or object of the forceps is to facilitate the delivery of the child. This does not mean that the instrument is never to be used unless, in the judgment of the accoucheur, delivery could not be accomplished without its use. Such a rule which has often been followed in the past by timid or ultraconservative obstetricians has frequently led to the death of the child, and not infrequently to the death or serious injury of the mother. The words of Lusk in this connection are wise and sensible, "The forceps is applicable (1) in cases where the ordinary forces operative during labor are insufficient to overcome the obstacles to delivery; (2) in cases where speedy delivery is demanded in the interest of either mother or child." In the majority of cases, as Lusk also states, the interests of the mother and the child are identical.

The forceps is particularly designed for the delivery of the fetal head, but there are occasionally instances in which it may be used for the extraction of the breech. We desire to emphasize the fact that such cases are exceedingly rare, and it must not be forgotten that its use upon the soft tissues of the breech will almost inevitably be attended with more or less bruising or laceration. One should not yield to the temptation to use it for this purpose, for which it is not designed, except under the most urgent indications. Of course, when one is certain that the child is dead a greater degree of latitude is permissible.

There are various mechanical ends which may be accomplished with the forceps, including traction, compression, rotation, dilatation, and leverage. It is primarily and principally an instrument for either direct or axis traction. The time has not yet come when axis traction will be used exclusively by all who have occasion to make use of the forceps. Jewett states that one who has a good axis-traction forceps needs no other, but this positive dictum will not apply, at least to the present generation.

There are plenty of cases in which the head is low in which delivery can be much more easily and comfortably accomplished with the short, straight Smellie forceps or the almost universally applicable Elliot forceps than with the more cumbersome axis-traction instrument. The personal equation in such matters is a very important consideration, and it is easy to comprehend that one who is constantly using the axis-traction instrument will attain to such a degree of dexterity that he will prefer to use it on all occasions. But is that not equally true of any other instrument? The important factors after all in successful midwifery are familiarity with one's tools, wide experience and serious attention.

Many rules are laid down by obstetrical writers as to the degree of traction which is proper. They are all fallacious when stated without reserve, and every person who assumes the responsibility of practising surgical midwifery should be competent to frame his rule for action in each particular case. Whether he should brace himself firmly when pulling, whether he should use one hand or two, whether he should maintain the forceps until the head is completely delivered, etc., is a matter for individual decision based upon the conditions by which one is confronted.

One golden rule, however, is universally applicable —that the amount of mechanical interference in this infringement, this necessary infringement, upon a natural process should be the irreducible minimum, and in accordance with the mechanical relations between the fetal head and the cavity through which it is to pass. The true midwife should merely endeavor to help nature. The forceps is an instrument of compression, it must be so or there would be no occasion for its use. The head could not pass through the maternal passage, even when each is of ordinary dimensions, without compression, and the resiliency of the cranial bones is such that this is not unanticipated, but the degree of permissible compression is another matter. The primary purpose of the forceps is not compression and the resistance of the head, of which one is ever conscious while exerting traction, must be the guide as to the amount of compression which is exercised. If one does not feel sufficient confidence in his ability to properly gauge the compression upon the head to prevent injury to it he should equip his forceps with a dynamometer, such as that of Stein for example, which will constantly indicate to him the compression effect of the traction which he is exercising. Or if he is using the Elliot forceps he should draw out the screw pin in the end of the handles, after the instrument has been adjusted to the fetal head. The handles being thus brought in contact with each other no pressure upon them can compress the head unduly.

Or a forceps may be equipped with a safety lock, which has recently been devised by Gallant, which will prevent forcing of the blades together during traction. When the thumb screw on this lock is set, the blades will be securely fastened, and no pressure

upon them will change their relations to the head from those to which they have been conformed. If none of these devices is used it should never be forgotten that pressure upon the handles of forceps which are crossed, and that includes all forceps which are serviceable to the average obstetrician, necessarily approximates the apices of the blades, as is the case in a pair of scissors. That may mean injury to the fetal structures which are included between the apices. The forceps of Palfyn (1723), Thenard (1800), and Chassagny (1891) have parallel blades. The last of these is fastened at the shanks with a rivet, and at the end of the handles with a bar. They are merely mentioned because of their historical interest. They are advocated by their designer because of their leverage value, which would not appeal to most obstetricians. The forceps is often exceedingly useful as an instrument of rotation. If it has been applied before rotation has been completed and traction is intelligent and moderate, the uterine contractions assisting in the delivery, the rotation of the forceps readily follows the movement of the head. If the head is somewhat large, relative to the pelvis, this movement of rotation should be deliberately effected by the obstetrician. If the position has not been clearly made out before the forceps is applied, traction and rotation should be undertaken cautiously, lest they be exerted in an improper diameter of the pelvis. If great resistance is offered to rotation in the right oblique diameter, the direction of traction should be changed to the left oblique. Of course the better way is to examine the head carefully with the hand in the vagina before determining the direction in

Fig. 2513.—Gallant's Safety Lock.

which traction is to be made. When the head has been thus rotated, it will usually be necessary to remove and readjust the forceps before completing the delivery. In occipito-posterior positions rotation with the forceps is of the greatest service. Such a procedure was regarded by the older obstetricians as undesirable or even improper, and it is true that with a forceps which has an exaggerated pelvic curve, the rotation of the head with consequent reversal of the position of the blades may mean injury to the maternal soft parts. With the Luikot forceps, in an experience covering many cases, the writer has never observed any injury to either mother or child from this procedure. It is almost absolutely essential to remove and readjust the blades after rotation from the occipito-posterior position, though delivery without harm is possible even in this unusual and improper mode of using the forceps.

The forceps may be used for the dilatation of the os uteri, somewhat as a uterine dilator is used in an

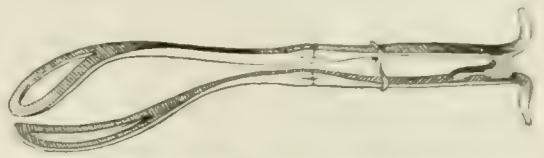


Fig. 2514.—Valette's Forceps. Each branch has a bayonet curve, and the branches are paralel instead of crossed.

unimpregnated uterus. It is not recommended for this purpose, in fact there is more or less danger of tearing the tissue in thus using it. It has occasionally been useful to the writer and is only mentioned as one of the possible emergent uses to which the forceps may be put when the os is not fully dilated.

Finally, the use of the forceps as a lever is one about which there is great difference of opinion and one which is certainly debatable. To either one blade or both blades of the forceps may the lever action be given. The vectis is practically a single blade of a forceps and it was used largely on account of its lever action; of course it was also used to a moderate extent on account of its action as a rotator.

Osiander in 1821 was the first to deliberately advocate the lever action of the forceps and he declared that he had delivered many living children by this means, when he could not possibly have delivered them in any other way. The elements of the lever when the forceps is thus used are: (1) The fetal head which is the weight or resistance; (2) the point of support in the maternal tissues which is the fulcrum, and (3) the power which is the force applied to the extremity of the handles by the hands of the accoucheur, and transmitted to their shanks at the point of support. A force of this kind may be very mischievous and result in exaggerated compression of the head and a vicious form of traction. Consequently this teaching of Osiander has long been held up as faulty by obstetrical writers, notably by such eminent German writers as Winckel and Von Siebold. The danger of Osiander's teaching is in making leverage a rule of practice and not in its occasional employment. When the head is wedged in the pelvis, and will not yield or will yield but slightly to direct traction, a leverage action from side to side will frequently be effective and will enable one to bring it to the pelvic outlet where direct traction can then be employed. With suitable safeguards against compression and with careful and deliberate action to prevent injury to the maternal tissues this measure will often prove very helpful. It has served the writer well on many occasions and he has never seen any harmful result from its use in his personal practice.

Structure of the Forceps.—The forceps consists essentially of handles, lock, shank, and blades. In the axis-traction forceps there are also traction rods and a cross bar with suitable attachments which are connected with them. It should be made entirely of tempered steel, the blades being particularly well tempered to prevent springing or yielding. The wooden handles have given place to those of solid steel which can be more readily made aseptic than the wooden ones. The handles should have indentations along their entire length ensuring a better grip than with those which are smooth.

The lock which is preferred in this country is the English lock. The French lock is generally used in France, and a combination of the English and French lock in Germany. These various locks have already been described. The shank is the narrow portion between the handles and the blades. It is unimportant whether its two elements are superimposed one upon the other, or are side by side. It should not interfere with the shoulders at the upper end of the handles which furnish a useful support for the fingers of one hand while traction is being performed with the other. The blades may be fenestrated or solid; the latter have a comparatively limited use. The fenestræ are ovoidal in shape and are limited by a narrow, but very strong border. The blades are concave inwardly, thus constituting the cephalic curve for adaptation to the fetal head. They also have a concavity above and a parallel convexity below, constituting the pelvic curve and adaptable to the curve of the pelvis. The dimensions of the cephalic curve are variable in different types of instruments. It should be broad enough to grasp the average fetal head firmly and not broad enough to slip; three inches is a good average measurement for its greatest width, and its length should be from six to seven inches. The apices or tips of the blades should be from seven-eighths of an inch to an inch apart. The pelvic curve, from end to end, should measure from three and one-fifth to four inches, in long forceps, and from two and a half to three and a fifth in short ones. The entire length of the instrument should be from fourteen to sixteen inches, of which the distance from the lock to the tips of the blades should measure from nine to nine and a half inches. The length of the short forceps should be three or four inches less than that of the long ones, and the length of the blades proportionately less. The edge of the blades should be rounded and absolutely smooth in all cases.

There should be no suspicion of nicks or dents in them, for it must be remembered that such imperfections might not only scratch or tear the maternal tissues but might also be the bearers of infectious material. The entire instrument should be nickel or silver plated, highly polished, and always immaculately clean.

The number of varieties and modifications of typical forceps is enormous and especially confusing to an inexperienced beginner in obstetrical work. Siebold says that in 1838 the number of varieties which had been described was 144. There must be double that number at the present time. Our advice to the beginner would be either to purchase an axis-traction forceps and perfect himself in its use, remembering as Jewett, whom we have already quoted, has said, that it will be sufficient for all conditions if well understood and well handled; or to purchase a good type of long forceps, the Elliot for example, which may be equipped with traction handles or the tapes of Poulet whenever axis traction becomes necessary. An axis-traction forceps costs from twenty to thirty or forty dollars, and the other combination not more than ten or twelve. To many a young practitioner the difference is well worth saving, and the results are almost equally good.

When Should the Forceps be Used?—Though the general indications mentioned by Lusk and quoted in a precedent section of this article will answer for general purposes, it is desirable to be somewhat more specific if we wish to get a clear idea of the function of this invaluable instrument. First of all the patient must be a proper one for such an operation from an anatomical point of view. We should not expect a successful result if an attempt were made to extract a fetus through a very irregular and greatly deformed pelvis; the forceps presupposes fairly good anatomical conditions. Consequently in every suspicious case careful examination of the pelvis and determination of the relative measurements of fetal head and maternal pelvis to each other must first be made. The corollary of this naturally is that if a fetal head is very large, hydrocephalic or with an occipitomental diameter greater than that of the transverse diameter of the brim of the pelvis, the case is not one for the forceps. Again, the fetal head may be so small that the cephalic curve of the forceps will not hold it with sufficient firmness and the blades will repeatedly slip when traction is made. The forceps should not be used if the maternal passage is obstructed. If there are tumors of any considerable size of the uterus or vagina, they must be removed before the forceps can be successfully applied. The vagina and vulva may also be so small and rigid that successful delivery through them would be problematical. The forceps cannot be applied until after the membranes have been ruptured and retracted over the fetal head. A child may be born spontaneously with unruptured membranes, but to deliver with forceps might detach the placenta prematurely and induce severe hemorrhage. As a matter of fact the writer has never seen a case in which the membranes were so tough that the forceps could be applied to the underlying head without rupturing them. Equally the os uteri must be sufficiently dilated to introduce the blades with readiness. Full dilatation is not always necessary though it is preferable. It is not usually desirable to pass them through an opening one and a half inches in diameter as did occasionally the late Dr. Isaac E. Taylor with his very narrow bladed forceps.

Application through a partially dilated os, perhaps with an edematous anterior lip, and very slow traction will sometimes overcome the difficulty and in such a case the forceps, in conjunction with the fetal head, plays the rôle of a dilator. It goes without saying that the fetal head should be in a position in which it can be grasped by the forceps with mechanical advantage. It is this fact that often makes applications above the brim so very unsatisfactory and often so disastrous to the child if not to the mother. Some authorities say that a child should be living to indicate a forceps operation. It would seem to the writer a matter of option or rather of judgment whether, if the child were known to be dead, perforation should be preferred to forceps for its delivery. Perforation is never a nice operation for the unskilled.

The indications for the use of the forceps may be regarded from the standpoint of the mother and also of the child. The indication which presents itself most frequently on the part of the mother is a prolonged labor, particularly if the patient is a primipara, in which not only the forces of the uterus are exhausted but the strength of the mother as well. Her courage is also exhausted, she feels that nothing has been accomplished, and she looks to the immediate future with anxious foreboding. The majority of forceps cases, especially in private practice, are of this type. If in addition to the exhaustion of the patient the temperature has become elevated to 102° F. or more, the prudent obstetrician will wait no longer for spontaneous delivery but will proceed to complete it artificially. In the presence of serious disease of the mother the time for assisting nature will come more quickly than when no such complication is present. This must especially be remembered in cases of heart disease. Many a woman with a serious heart lesion has perished in labor because her accoucheur did not use forceps or used them too late.

Should labor come on in connection with tuberculosis, typhoid fever, pneumonia, nephritis, or various other acute or chronic diseases the moment for using the forceps must be carefully and promptly chosen, primarily in the interest of the mother. In women who are paralyzed the use of the forceps should be predetermined and carefully carried out as soon as dilatation is sufficient to permit its accomplishment. Various accidents to the mother furnish indications

for the use of the forceps, the most frequent of which is convulsions. Any obstetrician who has witnessed the grim and terrifying phenomena of this complication does not need to be reminded that the uterus should be emptied as speedily as possible.

To be sure convulsions frequently occur after the uterus has been emptied, but it has always seemed to the writer that one great evil the less was to be contended with in these terrifying cases if the child were already in the world and, for the time, could be dismissed from consideration. The same holds good even to a greater degree when hemorrhage, especially internal hemorrhage, complicates the situation; indeed we can seldom if ever look for the continuance of life in either mother or child when concealed hemorrhage occurs, unless the uterus can be promptly emptied and an attack made upon the source of the bleeding. Hemorrhages which are external form a less urgent indication for the forceps operation, but the conditions of the circulation during labor are such that the sooner the child is removed, the more effectually can we deal with this important complication.

Bruises and excessive congestion of the maternal tissues also furnish indications for the timely use of the forceps. The danger of hemorrhage from greatly distended veins and of infection in these cases is very pronounced. It is seldom possible to make them worse by the resort to instrumental delivery and we may be able by this means to forestall a very undesirable chain of events. Should the uterus have ruptured or any other serious accident have occurred, the extraction of the child with the forceps will be the first step in remedying a very undesirable situation. In placenta previa the forceps will sometimes be required after the placenta, or a sufficient portion of it, has been liberated.

The indications for forceps delivery on the part of the child are fewer than from the maternal point of view. Of course, except when a child is greatly deformed or otherwise seriously diseased, the supreme desire should be (the safety of the mother always being held in view) to deliver him alive and uninjured. Unfortunately we have not many data to inform us as to the child's physical condition during his voyage through the maternal canal. We can keep ourselves informed, however, in regard to the fetal circulation and should the pulse rate, as indicated by auscultation, show a very marked acceleration, above 160 per minute, and be feeble in character, or should it become unduly slow, less than 100 per minute, and irregular, or very weak, prompt interference will be necessary to save the child's life. The same is true should there be prolapse of the cord with feeble or intermittent pulsations. Unless it is possible to deliver the child very quickly it has always seemed better to the writer to replace the cord, carrying it up high enough by the aid of suitable forceps, if necessary, to eliminate the pressure from the advancing head, or the squeezing from the forceps. If the cord is coiled around the neck or body of the child it must be slipped off if possible. The task is a very difficult one, often impossible of accomplishment. But it must be remembered that under such circumstances, the placenta remaining undetached, the further the extraction proceeds the tighter the cord becomes and the circulation may be fatally interfered with. The writer can recall at least two cases of this character.

Malpositions of the fetal head are also an indication for the forceps and particularly is this true of the occipitoposterior positions. Prolonged and ineffective pains with no advance of the head and no marked tendency to rotation require the application of the forceps, and the writer's experience has been that one is inclined to wait too long before using them. Having determined the faulty position and also that rotation is not taking place, why wait until the mother is utterly exhausted before giving her the relief which instrumental delivery will afford.

Dangers which Attend the Use of the Forceps.—The forceps is not an instrument of precision nor is its use unattended with danger both to the mother and the child. One of the most frequent forms of injury to the mother is associated with its unskilful introduction. Not infrequently one or both blades are introduced outside the cervix, the latter, of course, not being fully dilated. The writer has seen the entire cervix torn off by such unskilful practice, with fatal consequences. If the instrument is applied when dilatation is incomplete and the head high up or only partially engaged, it is almost certain to slip unless the head can be very easily drawn down. This frequently means bruising or laceration of the uterus or vagina or both. Oblique or reversed position of the forceps during traction is prone to result in lacerations of the vagina or in indentations which may be followed by sloughing. It is quite possible that such indentations may result in fistula of the bladder or rectum. Various accidents may follow too rapid or unskilful extraction, such as bruising of the perineum or the soft tissues of the vestibule. The coccyx is not infrequently fractured and rarely the bones of the pelvis, especially when the attempt is made to drag the head through an irregular and badly deformed maternal pelvis. Even the symphysis pubis and the sacroiliac synchondrosis have been badly injured by injudicious and unskilful forceps operations. Not all these injuries are avoidable. The indication for the use of the forceps may have been never so clear and its manipulation never so skilful and yet the result may be severe injury to the tissues. Most obstetricians of experience will recall cases in which the tissues of the uterus or the vagina or both have so little resisting power, or are so friable, that they will split, as wet paper tears, when the fetus is extracted and they are subjected to this unusual pressure and tension. We have seen such a tear extend high up into the uterus.

All sorts of injuries are also inflicted upon the child with the forceps. When the instrument is applied to the soft tissues of the breech, and force to any considerable extent is required, it will be almost an impossibility to avoid bruising or lacerating them. In every irregular application of the forceps to the head, a bruise or dent will be produced which may disappear after a few days or may last during life.

The danger to the child from compression with the forceps is great. Especially if it is applied when the head is high up and before it has undergone the moulding process, which it experiences in passing through the pelvis, is this danger present. It may result in deep indentations with permanent bad results, in facial paralysis, in unsightly scars, in annoyingly conspicuous birth marks. It may mean pressure or fracture of the frontal or parietal bone. It may mean compression of the brain with or without hemorrhage, and subsequent epilepsy, imbecility, or idiocy.

Thus it will be seen that danger and death lurk in the path of the forceps when it is injudiciously used and alas! not infrequently when it is used properly and skilfully. Furthermore, Winckel, whose opportunities for observation have been vast, attributes a large portion of the mortality of parous women and their necessity for one operation after another to the unwise use of the forceps. Pinard condemns the unnecessary use of this instrument, while Faucheux of the Clinique Baudelocque (Paris) declares (1) that forceps should not be used until the fetal pulse becomes very rapid or the mother's condition is dangerous; (2) that the instrument is dangerous because of its forty-four per cent. morbidity, and (3) that it may injure the child for life and should be avoided by mothers if they would have healthy children.

We do not agree with these pessimists and Jeremiahs. They judge from their experience, probably, and we from ours; and we have seen no such percentage of morbidity among the mothers nor a sixteen per

cent. mortality among the children. We are quite willing to admit the possibility of danger from the use of the instrument, especially when in careless or clumsy hands. But that is nothing more than can be said of a knife or almost any other useful instrument.

Frequency of the Use of the Forceps.—The frequency with which the forceps is called into use is by no means a constant quantity either for individuals or localities. In former days it was used far too infrequently, and many valuable lives were lost because of timidity or unjustifiable delay in using it. There seemed to be a kind of stigma attached to the necessity for its use; it was employed apologetically as it were. Smellie regarded as one advantage of his short forceps the fact that they could be carried in the pocket and slipped over the child's head without the knowledge of the patient or of the assistants. The dread of operations and of instruments of all kinds was far greater in his time than it is at present. Now we have probably gone too far in the opposite direction and the slightest excuse is all that is required to apply the forceps and terminate the labor. Once it would have been deemed unjustifiable, almost criminal, to terminate the labor because one had some other pressing engagement to meet, perhaps another confinement or something equally serious. Now-a-days a doctor will sometimes, we fear, terminate a labor to suit his convenience or comfort although be it far from us to assert that he would do it if he thought his patient would suffer thereby.

At the Clinique Baudelocque in Paris there were 29,000 deliveries in the fifteen years between 1889 and 1904, of which 869, or 0.29 per cent., were forceps deliveries. In these 869 deliveries there was a maternal mortality of 0.29 per cent., a fetal mortality of 14.04 per cent., 26.58 per cent. of accidents to the fetus due to the use of the forceps, 43.95 per cent. of maternal accidents, and 45.34 per cent. of subsequent maternal morbidity, hence Faucheux, the reporter of these statistics (Fréquence et pronostic de l'application du forceps à la clinique Baudelocque, Paris Thèse, 1905), warns mothers not to have the forceps used when their children are born.

The statistics of Winckel, who is a very conservative obstetrician, show in the five years 1879 to 1884 at Dresden, 5,000 labors with 184, or 3 per cent., forceps deliveries, all under rigid antisepsis. Of this number 117 were primiparæ; in 108 cases the forceps was used in the interest of the child and in 52 in the interest of the mother. The mortality was 11 or 5.9 per cent. which seems high, but in more than a quarter of the 184 cases the condition was one of danger when the forceps operation was performed. Furthermore, Winckel blames the operators for the high mortality, since 4 out of the 11 died from infection, 2 from eclampsia with infection, 3 from rupture of the uterus, 1 from hemorrhage and 1 from pernicious anemia. At Winckel's clinic in Munich in four consecutive years he had 3,500 deliveries with 87 or 2.49 per cent. forceps cases. Only 1 woman died, 1.15 per cent., and 13 children, 15 per cent.

It is to be noted that in very large series, including many thousands of cases, the percentage of forceps cases and usually the percentage of forceps accidents will be lower than when the series is smaller. In the best hospitals throughout the civilized world the maternal mortality at the present time is practically nil, and the fetal mortality is also very low. Of course there is always an occasional emergency case which is brought into a hospital in a dying condition, and such cases ought not to be included in the regular statistics showing the hospital work. There is every reason to believe that the morbidity is very much lower after forceps operations than in the statistics of Faucheux.

All of this must signify that the forceps when intelligently and judiciously used is beneficial rather than harmful. In private practice the experience of those who work among all classes of people, the rich and the poor alike, the general practitioners, will give one the best idea of the frequency of the use of the forceps in this sphere. We should say that its frequency was one case in from six to fifteen. A very good general rule was that of Parry who states that he was not in the habit of waiting longer than two hours after labor had been arrested, from whatsoever cause, before proceeding to apply the forceps.

Preparations for Using the Forceps.—There are certain preliminaries which should always be gone through with, if possible, before a forceps operation in order to insure the best results. If the patient is in a hospital she will be taken to its operating room and the procedure will then be carried out along the same lines which would be observed in any other surgical operation. If the operation is to be done at a private house and the proper facilities are wanting, the only prerequisite is the greatest possible degree of cleanliness in the surroundings and in the appurtenances which relate immediately to the operation. If an operation is apparently to be a short and easy one it may be performed with the patient lying upon her bed. It has long been the preference of the writer, however, to perform such operations upon a suitable table for he believes that they can be done better in this way, and with greater satisfaction to the patient.

It is presupposed that the carpet and furniture of the room are properly protected with clean sheets and that there is an ample supply of towels, hot and cold water, antiseptic solutions, basins, slop-jars, and all other necessary appliances. The patient is placed upon the table, the bladder and rectum emptied, the hair shaved from the pubes and adjacent skin, the vagina and external genitalia irrigated with a hot sublimate solution and the patient's limbs and body protected with clean sheets. A twisted sheet is passed behind the neck and around each thigh in the extreme lithotomy position. The Walcher position of exaggerated extension of the lower limbs may be used if it is deemed desirable to obtain the additional space in the pelvis which this position affords. The dorsal position of the patient is usually preferred in this country rather than the left lateral position which is common in England. The patient is, of course, under surgical anesthesia, ether being preferable if the operation is likely to be difficult or long.

If the operation is an elective one the os should be fully dilated, the hand being used, in any case if necessary, to complete the dilatation.* The position of the fetal head should be accurately determined, the hand being passed into the uterus for that purpose, if necessary.

The condition of the fetal circulation should be noted, for a very rapid pulse will necessitate expeditious action. It goes without saying that the accoucheur has prepared himself as thoroughly and as carefully as he would for any surgical operation. Rubber gloves should be worn but this does not imply that the hands and arms should be less carefully cleaned and scrubbed than if the gloves were omitted. The forceps must be sterilized and kept in a pitcher of hot water until required for use, and all the necessary instruments for repairing wounded tissues should be carefully laid out in a convenient place before the operation is begun.

The Forceps Operation.—The forceps may be applied to the head above the brim of the pelvis, within the cavity of the pelvis, or at the outlet, and the danger and difficulty of the operation diminish in this order. The instrument may be applied with reference only to the sides of the pelvis, or with direct reference to the head of the child, the former being called the pelvic and the latter the cephalic applica-

*The Bossi and other powerful dilators should be avoided if possible.

tion. Jewett advises that the latter, if necessary, be made only by an expert. It is usually more difficult than the former, involves much more manipulation within the vagina, and consequently exposes the patient to greater risk of infection. In the great majority of forceps operations the sides of the pelvis are chiefly considered by the operator and it is this variety which we are about to describe.

The rule laid down by an obstetrical teacher many years ago is a good one: that one first applies the left blade, with the left hand, to the left side of the patient. It is held lightly, nearly vertical but inclined somewhat to the right. Two or more fingers of the right hand are introduced into the vagina, and within the cervix. Along these fingers as a guide the blade is passed, hugging the left side of the pelvis as closely as possible. It should feel its way around the side of the head, avoiding all obstructions until one is conscious, it cannot be more accurately described, that the limit of the head has been passed, and that the blade embraces a portion of the head easily and freely. The handle is then dropped and the right blade is similarly introduced. If this maneuver has been properly carried out the blades will fall together and can be readily locked. If locking does not take place without the use of force there is a fault in the adjustment of the blades and their position must be greatly changed, one at a time, until the correct

Fig. 2515.—Introduction of the Forceps. (Lusk.)

position for easy locking has been found. One must remember that they are held in place by the sides of the pelvis and that the ends of the handles will be separated in proportion to the separation of the apices of the blades.

If the head has already rotated, and is low in the pelvis, the handles of the forceps will look forward. If the head is high and has not rotated the handles will be oblique, looking to one or the other side of the patient. In the latter case the first movements of traction must be with the object of completing rotation, after which the forceps must be reapplied and direct traction made. If the resistance of the head is not great, the traction efforts need not be excessive, one hand being often sufficient for the handles, while the fingers of the other rest upon the shoulders, below the lock. If resistance is considerable both hands must be used and it may be necessary to brace one's self to give greater steadiness to the pull, though some writers give warning that this must not be done. Compression of the handles must be very moderate lest the head and neck of the child suffer in consequence. The traction efforts will measure from twenty to seventy pounds, according to the resistance. The traction must be made in the central axis of the pelvis, first downward and backward, then forward, and finally upward as the head opens the vulva. The writer's custom is to remove the forceps at this time, and either let nature complete the operation, or by gentle pressure upon the perineum force the head outward after the tissues are sufficiently stretched.

Fig. 2516.—Forceps Applied to the Head at the Brim. (Lusk.)

Unless the traction operation is a very short one the traction should be intermittent, a pull and then an interval of a minute or two, loosening the blades to relieve the pressure upon the fetal tissues. Direct traction is preferable to swaying or pendulum movements, but if the head fits the pelvis very snugly the pendulum movements furnish a leverage which is frequently very useful. Of course it must be used intelligently and cautiously. If an axis-traction instrument is employed the blades should be introduced in the same manner as has been described for the ordinary instrument, and when it has been locked the fixation screw must be set to indicate the pressure upon the head which is to be exerted by the blades. Traction is then made with the handle of the traction rods, one hand being usually sufficient. The motion

Fig. 2517.—Blades Adjusted to the Head at the Outlet. (Lusk.)

of the handles of the instrument and the direction in which they point indicate the direction in which traction is to be made. When the head has reached the outlet, delivery may be completed, either with the traction bar or with the ordinary handles of the instrument. In occipitoposterior positions of the fetal head it is the writer's experience that the forceps will almost universally be required. It is a mistake, however, to try and drag the unrotated head through the undilated birth canal, for the head descending in this position does not act as an efficient dilator, and the instrument will almost certainly slip when great traction force is used. The forceps therefore having been carefully adjusted, the first effort which should

be made should aim at the rotation of the head. This having been done, the forceps can be reapplied and traction performed with good mechanical advantage. This procedure has been found by the writer superior to the rotation of the head and body by the hands. The forceps may be applied to the sides of the head in face presentations and if rotation is incomplete it may be so effected as to bring the chin under the pubic arch: the chin, face, and vertex then being delivered in succession. This applies only to cases in which the chin is anterior. The forceps may also be applied to the after-coming head in breech presentations, the procedure being the same as in head-first presentations with the occiput anterior. When the head has been decapitated and remains in the pelvis it should be so manipulated, by the hand within the vagina aided by pressure of the other hand upon the abdomen, that it may be brought if possible into the occiput anterior position. The forceps may then be cautiously applied and delivery effected in the usual manner. The forceps will occasionally be required in breech presentations but it is always an operation of difficulty and danger. It is only adapted to those rare cases in which a foot cannot be brought down nor the fillet or hooked finger be adjusted to the groin. The best application is over the trochanters for there the bony resistance is most effectual. If one of the blades were adjusted over the pubes the pressure upon the abdomen would be disastrous. Traction must be very gradual and the compression as light as possible. Even then it is scarcely possible to avoid wounding the delicate fetal tissues.

ANDREW F. CURRIER.

Formaldehyde, formic aldehyde, methyl aldehyde or oxymethylene (H.COH), is a gas whose saturated aqueous solution is known as *formalin* or *formol.* The method of manufacture used now on a large scale is a modification of that used by A. W. Hoffmann, who introduced formaldehyde in 1867. By means of superheated steam passing through a copper coil, methyl alcohol is vaporized under pressure in a steel chamber, from which it issues with great force and mixed with a definite quantity of air, and then passes through a double tube converter. The inner tube of this is perforated with very fine holes and separated from the outer tube by broken coke, and the whole is kept at a dull red heat. As it passes through this heated coke, the vapor is oxidized to formaldehyde, and this is either condensed by extreme cold to a liquid, or cooled and dissolved in water by agitation. Copper filings, spongy platinum, or any porous material may be substituted for coke. The gas is usually generated on a small scale by heating paraformaldehyde, though methyl alcohol can be employed by heating in a tin vessel so that the vapor will pass through a perforated red-hot copper plate. The reaction is: $CH_3OH+O=CHOH+H_2O$. The yield is said to be only twenty per cent. from commercial wood alcohol. Other methods of manufacture are by the complete oxidation of ethyl nitrate; by heating a mixture of ethylene and oxygen to 400° C.; by the dry distillation of calcium formate, etc.

Formaldehyde is a colorless gas of pungent, penetrating odor, and very irritating to the eyes and nose. Its saturated cold aqueous solution (formalin) contains from thirty-five to forty per cent. of the gas by weight, is colorless, has a sharp taste, and mixes freely with water, alcohol, and glycerin. The gas is more soluble in methyl alcohol than in water. Its chemical affinities are extensive. It is rendered inert by alkalies, deodorizes hydrogen sulphide, and is the basis of many aniline colors and new synthetic remedies, such as urotropin, bismal, tannoform, etc. It reduces Fehling's solution, produces a black precipitate with ammoniacal silver-nitrate solution, and white precipitates with dilute aqueous solution of aniline and with ammonia and bromine water. Henner's test, sensitive 1 in 200,000, consists in superposing a mixture of very weak carbolic acid with the suspected liquid upon concentrated sulphuric acid; a rose-violet ring at the line of contact indicates formaldehyde. A modification of this is to dissolve 0.1 gram morphine hydrochloride in 1 c.c. of sulphuric acid and add to this the suspected liquid. In milk and such fluids, however, these tests may be obscured by the charring of the organic substances by the acid; hence, in such a case, the formaldehyde should be distilled off and passed into water, and then tested for. Jorrissen's test was designed for milk; shake together 25 c.c. of milk and 10 c.c. of 0.1 per cent. aqueous phloroglucin, add 5 to 10 c.c. of one-third strength potash lye, and a transient salmon-red color indicates formaldehyde.

It is official in the U. S. P. under the title of *Liquor Formaldehydi,* Solution of Formaldehyde, which is an aqueous solution containing not less than thirty-seven per cent., by weight, of absolute formaldehyde. This preparation is sometimes called *Formalin.*

When formalin is heated, part of it is converted into paraformaldehyde (paraform, triformol, or trioxymethylene), which separates as a white insoluble flocculent mass, capable of again yielding H.COH gas. Formaldehyde renders gelatin insoluble, forming elastic translucent masses, so it has been used to replacetann in in making leather and to harden gelatin films in photography. Formaldehyde gelatin is employed as an absorbable antiseptic. When added to serum albumin, formalin prevents coagulation by heat; added to calcium carbide, it retards the evolution of acetylene gas. It neutralizes alkalies by forming with them complex substances, that with ammonia being hexamethylenetetramine.

It is said not in any way to affect the textile character of wool, cotton, fur, silk, or leather; and it does not change their colors except in the case of iron-containing dyes or a few of the aniline colors such as fuchsin (aniline red). Its aqueous solution attacks metals; consequently the dry gas only should be used for sterilizing instruments. In 1886 its powerful bactericidal properties were reported by Loew, and it has now become an almost universal disinfectant (see *Disinfectants*). Rubber goods, catheters, etc., may be kept sterile in a weak solution for a long time without harm. Hoffmeister, Hirst, and others have used it for sterilizing cagtut.

It is also used largely as a hardening and fixing agent, and as a preservative for anatomical and biological specimens. These, especially plants, tend to retain some of their brilliant colors, and do not shrink as they would in alcohol. Plants slowly discolor the solution by giving up their tannin. As formaldehyde has little penetrating power, openings should be made so that it may permeate the interiors of specimens; otherwise they may rot, even in strong solution. Moulds have been found growing on tissues apparently saturated with solutions of five to ten per cent. strength. Orth's hardening and fixing formula is: Müller's fluid, 100 parts; formalin, 10 parts. To be mixed just before use. Kaiserling keeps the specimen for twenty-four hours in formalin 75, potassium nitrate 1, potassium acetate 3, distilled water 100, then transfers to 80 per cent. alcohol for twelve hours, then to 95 per cent. alcohol for two hours. The specimen may then be mounted for sectioning, or kept in equal parts of water and glycerin containing 3 per cent. of potassium acetate. Before putting through alcohol, Carter leaves the tissues for from six to twelve hours in 20 per cent. formaldehyde solution with 5 per cent. acetic acid. Blood smears exposed to the vapor are firmly fixed, and may be stained as by any other method of fixing. Blood on the hands becomes hardened and difficult to wash off.

Being difficult of detection in small quantities, it is used as a preservative of foods and medicines, vigorous prohibitive laws not preventing its widespread use by dairymen, canners, etc. In the strength of 1 to 20,000 it is said to preserve milk for several days, yet even this minute quantity has been shown by Annett and others to be harmful. It has been employed by pharmacists for the preservation of ointments, syrups, fruit juices, infusions, and various other articles which readily spoil. Mucilage of acacia, lard, cider, etc., remained sweet after a year, yet the odor of formaldehyde could not be detected at any time. Once added to an article, a portion of it remains persistently and cannot be driven off by heat. The best means of neutralizing it in vapor or in solution is by ammonia.

Physiological Action and Toxicology.—Formaldehyde vapor is a powerful irritant to the eyes and the mucous membranes of the respiratory tract. Applied in solution to the skin it smarts, but usually for a short time only. Severe urticaria is reported to have followed its application. The solution in glycerin is said to be less irritant. Taken by mouth it retards digestion even in small dosage, especially the pancreatic digestion of albumin. In strong solution it may cause vomiting. It weakens pulse and respiration and is depressing to the vital functions. The ingestion of several ounces of formalin by an adult was followed by unconsciousness, marked pallor, cold clammy perspiration, increased respiration, and râles over both lungs. The urine contained formic acid. In a few hours anuria developed, and the next morning the coma disappeared, and the patient acted as if drunk, complaining of headache, conjunctivitis, and a sore mouth. He recovered in twenty-four hours (Kleuber). In England, the drinking of two ounces of a four per cent. solution resulted in death from heart failure twenty-nine hours later. The autopsy showed corrosive action on the esophagus and stomach. Fischer (1901) reported to the Chicago Pathological Society an experimental study of the action of formaldehyde on animals. Inhalation resulted in marked inflammation throughout the respiratory tract. Dosage by stomach produced vomiting, subnormal temperature, rapid weak pulse, and death. Sometimes the death was sudden. Necropsy revealed intense gastritis, with congestion, necrosis, and leucocyte infiltration. Intraperitoneal injections were followed by a fibrinohemorrhagic peritonitis of an intensity referable to the strength of the solution. Small repeated intraperitoneal injections of dilute solutions stimulated great connective-tissue proliferation. Eye instillations caused iritis. Every case showed early eosinophilia followed by general leucocytosis, and degenerative changes with focal necroses in liver and kidneys. Experiments in France show that fleas easily succumb to the vapor, but that to kill rats and mice requires as much as eight or ten grams to the cubic meter of air space.

The best local antidote is ammonia, though other alkalies are of some avail. Ammonia gas quickly neutralizes the irritating vapors in a room. For the stomach it may be given as the aromatic spirit of ammonia or the liquor ammonii acetatis. When formalin is swallowed, vomiting should be promoted, or the stomach emptied by lavage. Stimulants, especially aromatic spirit of ammonia and caffeine, and hypodermics of strychnine should be administered, external heat applied, and absolute recumbency enjoined. Demulcent drinks may be given to allay irritation.

Therapeutics.—As a general disinfectant and deodorizer this drug is undoubtedly without a peer, though its penetrating power is not great. In the respiratory passages it is of pronounced value as a prophylactic and curative in *influenza* and *pertussis*, and in allaying the cough and sweetening the sputum in *tuberculosis*. It is also used in *chronic pharyngitis*, in *atrophic rhinitis* (principally as a deodorizer), and as a *mouth wash*. It is said to be of less use in *diphtheria*, as it does not penetrate the dense membrane. A few drops of ℞ Aq. chloroformi ʒiij. (12.0), ether ʒss. (15.0), formaldehyde solution (six per cent.) ad ʒiv. (120.0) may be sprinkled on the sponge of a zinc respirator, and inhaled for fifteen minutes. Or one can use as a mouth wash or spray a mixture of forty per cent. formaldehyde solution ʒi. (4.0), glycerin ʒiv. (15.0), and water to make ʒiv.-vi. (120.0–180.0). The method of treating *tuberculosis* by cataphoresis, or the electrical transmission of formaldehyde directly into the human body, has given negative results.

For *suppurative otitis media* Reik recommends irrigation twice a day with ʒi. (4.0) of formalin in Oi. (500.0) of water. Ward uses five to ten drops of a one-per-cent. solution, and in *acute otitis* three drops at a time.

In the mycotic skin diseases, such as *sycosis*, *ringworm*, and *favus*, the strong solution may be applied every other day. Cures resulted from one to four applications (Salter, Daniel). For *seborrhea* Ravogli advises rubbing with ℞ Formalin, ʒi.-ij. (4.0–8.0); glycerin, ʒij. (8.0); aq. coloniensis, alcohol, āā ʒiij. (90.0).

Hyperidrosis pedis may be checked for a week or two (Hahn, Hirschfeld) by momentarily immersing the feet in pure formalin, or by applying it with a brush. Unna found formalin of value in *inoperable carcinoma*, as it deodorizes and mummifies the part. For *condylomata* and other soft skin protuberances he uses paraform collodion, which possesses the advantage of keeping the growth dry. Daniel rubs formalin into *warts* with a stick, and these shrink and come off without leaving a scar.

As a vaginal douche Crawford recommends formalin in *obstetrics*, and Van Winckel uses ʒi. (4.0) to a quart (one liter) for *endometritis* or for *vaginitis*, especially gonorrheal. It may be used in full strength in the treatment of *chancroids*.

Surgically it is an antiseptic of great power (see (*Disinfectants*), and is used for sterilizing the hands, dressings, sutures, and instruments. Hoffmeister, Hirst, and others recommend it highly for catgut. Hoffmeister's method is to harden the catgut on glass spools in four per cent. formaldehyde for twenty-four hours, then boil in water for ten minutes and keep in alcohol continuing five per cent. of glycerin and 0.1 per cent. of corrosive sublimate. Vandermarker states that it should not be used directly in wounds, as one per cent. solutions will destroy fresh granulations, and two per cent. will produce sloughs. Its combination with gelatin (glutol), however, is used thus by Schleich and others. Inoperable epitheliomata and sarcomata have been treated with injections of one-half per cent. solution (about twenty minims) followed by curetting of the hardened tissue. The bleeding had been slight, and the growths have practically disappeared after a few treatments (Mitchell, Thompson). Ravogli claims to obtain the same results from the application of a paste of rice powder, oxide of zinc, and formalin. In chronic tuberculous joints, tuberculous abscesses, and empyema, Hahn considers a one per cent. glycerin solution to be more efficient than the much used iodoformate glycerin.

In dentistry, paraformaldehyde is preferred, as, being in solid form, it can be placed in cavities, disinfecting them by slowly evolving formaldehyde gas.

The more common preparations and compounds of formaldehyde are:

Aldoform, which is said to liberate formaldehyde.

Aminoform, *Ammonio-formaldehyde*—synonyms for hexamethylenamine.

Amyloform—starch and formaldehyde.

Bismal—the bismuth salt of methylene digallic

acid, formed by the action of gallic acid on formaldehyde. Used as intestinal antiseptic and astringent.

Creoform, Creosoform, Kreoform—a non-toxic, tasteless, and odorless compound of creosote and formaldehyde. A strong antiseptic.

Cystamine, Cystogen—synonyms for hexamethylenamine.

Dextroform—formaldehyde and dextrin (see *Amyloform*, Vol. I.).

Eka-iodoform—iodoform and paraformaldehyde (see Vol. III.).

Euformol is a mixture of oil of eucalyptus, formaldehyde, thymol, menthol, etc.

Formacoll—synonym for glutol.

Formaldehyd-bisulphite (HCOH, $Na_2S_2O_5$) is a crystalline mixture resulting from the action of formaldehyde on sodium bisulphite in solution. It is claimed to possess the antiseptic properties of both constituents.

Formaldehyde-casein (Formalbumin) is an odorless, tasteless, coarse yellow powder, used in surgery as an antiseptic.

Formaldehyde-gelatin—used in photography and in surgery (see *Glutol*)

Formaldehyde-sulpho-carbolic acid [$(CH_2OH)_2.C_6H_3.OH$] is used as an antiseptic dressing for wounds.

Formaldehyde tannalbuminate—tannalbumin subjected to the action of formaldehyde to render it more resistant to the action of the gastric juice. The compound passes unchanged through the stomach, and as it is split up but slowly in the intestines, it gets well down in the bowel before it separates into its components. Used as an intestinal antiseptic and astringent.

Formaldehyde-urea is an amorphous, white condensation product of urea and formaldehyde in alkaline solution. It is insoluble in water. Used as a disinfectant.

Formalin, Formol—a saturated aqueous solution of formaldehyde.

Formanganate is a mixture of potassium permanganate and formalin. It is used to disinfect rooms.

Formanilid is used in a two or three per cent. solution for urethral discharge.

Formatol is a proprietary dusting powder containing formaldehyde.

Formin—synonym for hexamethylenamine.

Formo-chloral is an oily compound formed by the action of formaldehyde on chloral in the presence of concentrated sulphuric acid. It is used as an antiseptic.

Another compound of this name, used by Trillat as a deodorizer, is made by acting with calcium chloride on formaldehyde in solution in methyl alcohol.

Formoforin consists of formaldehyde 0.18, thymol 0.10, zinc oxide 34.44, and starch 65.28 per cent., and is used for sweating of the feet.

Formolyptol is said to contain formaldehyde and various balsams and resins.

Formopyrin occurs in white crystals formed by the action of formalin on a solution of antipyrin. It is insoluble in cold water or ether, but fairly soluble in boiling water, alcohol, chloroform, and acids, with the latter forming stable salts.

Formosyl is a preparation containing formalin, boric acid, phenol, and essential oils. It is used as a mouth wash and as a nasal douche.

Fortoin—cotoin acted upon by formaldehyde (see *Fortoin*).

Galloformin is prepared by acting on hexamethylene tetramine with gallic acid (see *Galloformin*).

Geoform—guaiacol and formaldehyde (see *Geoform*).

Glycoformol is a mixture of formalin, water, and glycerin.

Glyceroformol is said to be formed by the prolonged action of formaldehyde on glycerin. It is claimed to be more toxic than formaldehyde, but evidence for this statement is hard to find.

Hexamethylene-tetramine—the chemical name for aminoform, cystamine, cystogen, formin, and urotropin. (See *Hexamethylenamine.*)

Holzin is a sixty-per-cent. solution of formaldehyde in methyl alcohol used by Oppermann as a deodorizer.

Holzinol is a mixture containing formaldehyde and menthol.

Krameroform is prepared like tannoform, but from rhatany-tannin.

Lanoform is lanolin containing one per cent. of formaldehyde.

Lysoform is a soapy disinfectant containing formaldehyde (see *Lysoform*).

Naphthoformin is made from paraformaldehyde and the alpha and beta compounds of naphthol. It is used both externally and internally as an antiseptic.

Paraform is paraformaldehyde.

Polyformin Soluble and Insoluble—used in skin diseases (see *Polyformin*).

Preservalin—a mixture used by dairymen.

Protogen is an albuminous food obtained by acting on serum or egg albumin with formaldehyde. It is not coagulated by heat.

Quebrachoform, Quinoform, Querciform are prepared like tannoform (which see), but from the tannins of quebracho, cinchona, and oak.

Saligenin, also yielded by salicin, may be obtained by the interaction of phenol and formaldehyde.

Steriform Chloride and *Iodide*—formaldehyde five, pepsin twenty, lactose sixty-five, and ammonium chloride or iodide ten.

Tannoform—an antiseptic in skin diseases (see *Tannoform*).

Tannopin or *Tannon* consists of tannin and hexamethylene-tetramine, and is used in diarrhea (see *Tannopin*).

Tholaform contains menthol and paraform, and is used for sore throats.

Thymoform is thymol-formaldehyde (see *Thymoform*).

Triformol, Trioxymethylene—synonyms for paraformaldehyde.

Urotropin—hexamethylenamine.

W. A. Bastedo.
R. J. E. Scott.

Formanilide ($C_6H_5NH.COH$) occurs in colorless crystals. It melts at 46° C. (115° F.), and is readily soluble in water, alcohol, glycerin, and oils. It is antipyretic and analgesic and has been used in doses of gr. ij. to v. (0.13 to 0.3 grams), but it is said to depress the heart and produce cyanosis. It is certainly more toxic than acetanilide, probably owing to the greater ease with which it undergoes hydrolysis. Its chief employment is as a local anesthetic in two per cent. solution.

R. J. E. Scott.

Formic Acid.—H.COOH. Formic acid (also known as *aminic acid*) is a heavy, colorless fluid of a sharp, sour odor and taste, soluble in all proportions in water, alcohol, and glycerin. It may be prepared by heating oxalic acid with glycerin. It is exceedingly irritating, producing, when applied to the skin, redness, blistering, and even sloughing, and, taken internally, gastroenteritis and bloody urine. It has been used occasionally, locally, as a counter-irritant, applied diluted with an equal measure of water.

Edward Curtis.
R. J. E. Scott.

Formicidæ.—Ants. This family of hymenopterous insects secrete a venom which contains formic acid and other substances. Their bites usually cause nothing more than local irritation, but the bites of some tropical species are more serious. See *Insects, Poisonous.*

A. S. P.

Fort Crawford Mineral Well.—Crawford County, Wisconsin.

Post-office.—Prairie du Chien. Hotel and Sanatorium.

Access.—Viâ Chicago and Burlington, and Chicago, Milwaukee and St. Paul Railroads. Prairie du Chien is six hours from Milwaukee, Minneapolis and St. Paul, seven hours from Chicago, three hours from Madison, two hours from La Crosse and Dubuque, six hours from Austin, and nine hours from Des Moines. The town is one of the oldest in the State. The well from which the mineral water is obtained was bored in 1876. At a depth of 996 feet a strong flow of water was encountered, and ever since there has been a continuous stream, six inches in diameter and having a pressure of twenty pounds to the square inch. The well yields about 40,000 gallons per hour. By means of mains and hydrants it furnishes the city fire department, and affords an abundance of water for domestic purposes. It was soon learned that the water possessed medicinal qualities. An analysis by Professor Bode, of Milwaukee, showed the following results:

One United States Gallon Contains:

Solids.	Grains.
Calcium bicarbonate	0.62
Magnesium bicarbonate	10.97
Sodium chloride	90.20
Potassium chloride	3.80
Sodium bromide	0.13
Sodium sulphate	12.80
Calcium sulphate	15.38
Iron bicarbonate	0.23
Sodium phosphate	Trace.
Sodium bicarbonate	Trace.
Alumina	0.66
Silica	3.84
Organic matter	Trace.
Total	138.63

This is a valuable member of the widely useful alkaline-saline class of waters. It closely resembles some of the Saratoga waters in its mineral constituents, being, however, somewhat milder than those waters. Its chief effects are antacid, laxative, diuretic, and tonic. It is well adapted for the class of diseases to which such waters are applicable. It is also an excellent table water, and is used commercially. A well-equipped modern sanatorium with ample bathing facilities is conducted in connection with the well.

Emma E. Walker.

Fortoin, or methylene-dicotoin $[CH_2(C_{14}H_{11}O_4)_2]$ is formed by the action of formaldehyde on cotoin, and occurs in yellow, tasteless crystals or powder having a cinnamon-like odor. It is insoluble in water, slightly soluble in alcohol, ether, and benzol, and readily soluble in chloroform, acetone, glacial acetic acid, and alkalies. It has been used as a substitute for cotoin in the treatment of dysentery and the diarrhea which sometimes accompanies phthisis. The dose is four grains (0.25 gram). It is free from the sharp taste of cotoin.

R. J. E. Scott.

Foster, Frank Pierce.—Dr. Frank P. Foster was born in Concord, N. H., November 26, 1841, and was educated in the public school of that town. He attended lectures for a time at the Harvard Medical School, but later came to New York, receiving his degree from the College of Physicians and Surgeons in 1862. After an interneship of two years at the New York Hospital he became an acting assistant surgeon in the U. S. Army, and at the close of the Civil War established himself in general practice in this city. He at first showed a leaning toward dermatology, but later directed more attention to gynecology, although at no time did he regard himself in the light of any other than a general practitioner. Prior to 1870 vaccination was done almost wholly with humanized virus, either arm to arm or with scabs softened in water. Observing the dangers of this practice Dr. Foster urged the exclusive use of bovine virus and with the assistance of the officials of the New York Dispensary obtained the general adoption of that method. He was one of the founders of the New York Dermatological Society.

It was as an editor, however, that Dr. Foster was most widely known. His early training in English

Fig. 2518.—Frank P. Foster.

and the humanities in the Concord High School gave to his mind a literary bent which soon led him into medical journalism, first as a contributor of original communications and editorial articles to the *Medical Record* and other journals, and later as editor of the *New York Medical Journal.* He became editor of this journal in January, 1880, serving in that capacity for over thirty-one years, a record of professional editorial headship surpassed in this country only by Shrady, who was editor of the *Medical Record* for thirty-eight years, and by Issac Minis Hays, who was editor of the *American Journal of the Medical Sciences* for fifty-nine years. Dr. Foster was also editor of the monumental "Encyclopædic Medical Dictionary," the preparation and publication of the four volumes of which occupied his spare time for twelve years, of the "Reference Handbook of Practical Therapeutics" in two volumes, of "Appleton's Medical Dictionary," published in 1904, and of the medical terms in the "Standard Dictionary." For several years he was librarian of the New York Hospital Library, until that institution was discontinued and its books were transferred to the library of the New York Academy of Medicine. During the years 1909–1911 he acted as chairman of the Committee on Nomenclature of the American Medical Association. He died August 13, 1911.

Frank Foster was a man of high ideals, firm in his convictions but open-minded and charitable toward others whose views were not as his; a man of culture, well read in the classics, a French and German scholar, and a writer of pure English. T. L. S.

Fothergill, John.—Born at Carr-End, in the County of Yorkshire, England, March 8, 1712. After studying pharmacy in Bradford he went to Edinburgh, where he was graduated in Medicine in 1736. Later he continued his studies in Holland, France, and Germany. On his return to England he began practice among the poor of London. Soon after he began his work an epidemic broke out, giving Fothergill the opportunity, through the successful management of his cases, of establishing himself as one of the rising and brilliant therapeutists of the day. His fame soon spread causing the medical societies of London,

Edinburgh, Paris, and Philadelphia to confer honors upon him. With fame came wealth, so that he was enabled to establish a home at Lee-Hall, near his birthplace. Here he died on December 26, 1780.

Fothergill, through his intense interest in the sufferings of his fellowmen, his desire to aid and relieve, and his winning personality, coupled with his extensive knowledge of therapeutics, became a popular and highly thought of physician. He won not only the respect but the love of his patients. His deep interest in materia medica and therapeutics arose, probably, from his great knowledge of botany, and he has been recognized as one of the most famous therapeutists of England. He did not, however, confine himself to any one field, and his versatility was shown by his contributions to medical literature, the chief of which were: "The Cure of Sciatica," "A Hemiplegia Attended with Dropsy," "Experiments on Mixing Oils, Winous and Pinguious Substances with Water by Means of a Vegetable Mucilage," and "An Essay on the Preservation of Shipwrecked Mariners."

Fig. 2519.—John Fothergill.

E. L. J.

Fountain Park Magnetic Springs.—Champaign County, Ohio.

Post-office.—Fountain Park. Hotel and cottages.

Access.—Viâ Pennsylvania Railroad (P., C., C. and St. L., Indianapolis Division). The hotel is within five minutes' drive of the Fountain Park Station. The location is thirty-four miles west of Columbus and twelve miles east of Urbana. Fountain Park village was laid out in 1882 soon after the discovery of the springs. The site of the village is one of great natural attractiveness. The elevation is 1,200 feet above the sea-level and the surrounding country is gently undulating. The hotel and cottages are located in a beautiful tract of forty-three acres in which are numerous hills surmounted by groves of deciduous trees. Acme stone walks and driveways have been laid around the hotel grounds, and an artificial lake of sufficient size for boating constructed. The large lawn is adapted for all kinds of outdoor sports and games. Brush Lake, one mile east of the Park, affords rare attractions to the piscatorially inclined visitor. The waters at Fountain Park proceed from five flowing wells. The largest is 2,200 feet in depth and fills a ten-inch pipe at about twenty-one pounds' pressure. Following is an analysis of this spring, made in 1892 by Prof. E. S. Wayne, of Cincinnati:

One United States Gallon Contains:

Solids.	Grains.
Sodium chloride	13.64
Calcium chloride	4.22
Magnesium chloride	2.12
Potassium sulphate	2.61
Calcium carbonate	26.24
Magnesium carbonate	11.41
Iron carbonate	0.16
Silica	0.24
Organic matter	0.39
Total	61.03

This is an excellent water of the alkaline-saline-calcic variety. The presence of a small quantity of carbonate of iron will prevent debilitating effects on continuous use. The water has been found valuable in acute and chronic rheumatism, gout, dyspepsia, and diabetes. Two of the remaining four wells were analyzed in 1895 by Prof. H. A. Weber of the Ohio State University. They show the same general characteristics as Spring No. 1 (above). There is an excellent modern hotel in the Park. It contains well-equipped bath-rooms, under the charge of an experienced physician. Emma E. Walker.

Fourth Disease.—See *Roseola Scarlatinosa.*

Fowler, George Ryerson.—Born in New York, December 25, 1848, he was graduated from the Bellevue Hospital Medical College in 1871. After graduation he established himself in practice in Brooklyn where he soon acquired the reputation of a skilful and successful operator. He was surgeon to the Methodist Episcopal Hospital, surgeon-in-chief of the Brooklyn Hospital, senior surgeon to the German Hospital, and consulting surgeon to St. Mary's Hospital, the Relief Hospital, and the Norwegian Hospital. He was examiner in surgery of the New York State Board of Medical Examiners. During the Spanish War, in 1898, he served as surgeon of the Third Division of the Seventh Army Corps with Gen. Fitzhugh Lee. Later he acted as consulting surgeon and chief of the operating staff of the Seventh Army Corps, accompanying General Lee to Havana. He organized a system of hospitals for the use of disabled soldiers.

He died in Albany, February 6, 1906, following an operation for appendicitis, with which disease he was seized on the train while on the way to attend the centennial meeting of the Medical Society of the State of New York.

Dr. Fowler was a surgeon of repute and a special student of abdominal surgery. He was the writer of an authoritative treatise on the subject, first published in 1894, and in a revised edition in 1900. He was also the author of "A Treatise on Surgery," Philadelphia, 1906, and of numerous journal articles on surgical topics. T. L. S.

Fox, Tilbury.—Born in the south of England in 1836. He was the son of a physician and received his degree in surgery from the University of London in 1857. He became House Surgeon at the General Lying-in Hospital at Lambeth, and at this stage of his career took a deep interest in obstetrics, writing a paper on "Phlegmasia Dolens" and one on "Puerperal Fever." He occupied the post of Physician Accoucheur to the Farringdon General Dispensary. A little later through his study of the microscopic fungi attacking the skin and hair, he became so interested in dermatology that he devoted his entire time to the study and practice of skin diseases. In 1866 he was appointed Physician to the Skin Department of Charing Cross Hospital and soon after received the same appointment at the University College Hospital. In 1869–70 he delivered the Lettsomian Lectures on Eczema in London. He died, in Paris, on June 7, 1879.

Fox enjoyed the distinction of becoming one of the foremost dermatologists not only of England, but of the world. When he entered the medical profession dermatology had not received the attention it deserved, and it is due largely to his untiring work and study that it has attained such definite recognition to-day. He contributed much to dermatological literature, his first work on skin conditions appearing in 1863, entitled "Skin Diseases of Parasitic Origin." In 1864 his "Treatise on Skin Diseases" was published and was translated into French and Italian and became among the best known of his works. During the same year he published a paper on "Cholera in the East" and his "Dermatology of Egypt." He re-edited Willan's "Atlas of Skin Diseases" in 1875.

Later, together with another well-known physician, Dr. Farquhar, he prepared a scheme for obtaining a better knowledge of the endemic skin diseases of India for the India Office, which work obtained a permanent recognition in the Indian Department. He was also connected editorially with the Lancet.

E. L. J.

Foxglove.—See *Digitalis*.

Fracastori, Girolamo.—Hieronymus Fracastorius, the Latin form of the name by which he signed his treatises, was born in Verona, Italy, in 1483. Little is known of his life beyond the fact that he was a scholar, a physician, and a poet, and was for some years professor of logic at the University of Padua. His reputation rests chiefly upon two of his works. He wrote a celebrated Latin poem of marked literary excellence on syphilis, running through which, almost buried in a mass of mythological allusions we find a fanciful theory of its causation, a good clinical description of the disease, and praise of the remedial virtues of mercury and especially of guaiac. This is the first writing we have in which the word syphilis is applied to the disease. The author derives it from the name of a shepherd, Syphilus, who tended the flocks of King Alcithous. The god Sirius caused a torrid heat to fall upon the earth which slew many of the herd. Angered by the loss, Syphilus cursed Sirius, overthrew his altar, and sacrificed to Alcithous instead. The god, incensed, visited the, earth with a dire plague the profane shepherd being the first victim. Of greater medical value was Fracastori's treatise on "Contagion and Contagious Diseases," the publication of which marked a distinct advance in epidemiology. In it he formulated the doctrine of contagion (noting the possible agency of flies in the transmission of disease) and also distinguished the group of typhous diseases from the other malignant infections, including the plague. Fracastori died in or near Verona on August 8, 1553.

Of the works of Fracastorius the following are known: "Syphilidis, sive de morbo gallico, libri tres," 1530: "Di vini temperatura," 1554: "De sympathia et antipathia rerum," 1546: "De contagione et contagiosis morbis eorumque curatione, libri tres," 1546. His collected works were published in Venice after his death, in 1555.

T. L. S.

Fractures.—Classification and Definition.—For convenience in describing, and as an aid in understanding the exact lesions occurring in fractures of the bones it is important to separate them into categories based upon the characteristics which the various bone fractures are found to possess. A most practical, and at the same time comprehensive classification, is one which we adopt, with slight modifications, from the chapter on Fractures, by Eisendrath, in Keen's Surgery.

Seven categories are here distinguished:

I. According to their degree, into complete and incomplete or partial fractures, the latter including fissures, green-stick fractures, depressions, subperiosteal fractures, and the separation of a splinter or an apophysis.

II. According to the direction of the line of fracture, into transverse, longitudinal, oblique, spiral, comminuted, impacted fractures, and compression or crushing fractures.

III. According to their location in the bone, into fractures of the shaft, which may in turn be more specifically described as fractures of the upper, of the middle, or of the lower third, or may be named with reference to the adjacent portions of the upper or of the lower end of the bone, as subtrochanteric, supracondylar, supramalleolar fractures, etc., and fractures at the ends of the bones, the latter receiving the name of the part which the fracture transverses, *e.g.* fractures of the neck, of a tuberosity, of a process, of a condyle, etc. In this same category are included epiphyseal separations and articular fractures, the latter being distinguished into intraarticular fractures, juxtaarticular fractures, and articular fractures proper.

IV. According to their etiology, into pathological (spontaneous) fractures, fractures by muscular action and fractures by external violence (traumatic fractures). Fractures by external violence may in turn be advantageously placed in two groups, (a) those by direct violence, including gunshot fractures, compression fractures and crushing fractures, and (b) those by indirect violence, including fractures by direct thrust, fractures by avulsion (par arrachement), fractures by torsion, infractions or fractures by bending and fractures by leverage.

Fig. 2520.—Complete Fracture of Both Bones of the Leg High Up.

V. According to their relation to the overlying skin, into open and closed fractures, the older terms being respectively compound and simple fractures.

VI. According to the number of fragments, into single and multiple fractures.

VII. According to the involvement in the lesion of important structures adjacent to the fractured bone, into complicated and uncomplicated fractures.

Complete and Incomplete Fractures.—Our first division of fractures was into complete fractures and those that were incomplete or partial. A complete fracture is one which separates the bone into two or more fragments, where the line of fracture separates the whole of the head (or of its analogous part) or of the base (or of its analogous part) from the rest of the bone. Where the line of fracture is such as to split off from the bone less than this, the fracture is termed a partial or incomplete fracture.

Fig. 2521.—Incomplete Fracture of the Tibia. Fracture of the Internal Condyle. This shows the characteristics of a fracture by direct thrust from a blow, striking on the feet) in the relatively slight divergence of the fracture line from the axis of the bone. This is likewise a compound fracture in that the line of fracture enters the knee joint. It is also an articular fracture proper.

Incomplete or partial fractures include fissures or cracks in the bone without appreciable separation of the fractured surfaces. Such fissures are common in the bones of the skull, they are met likewise, occasionally, in the tibia, where the general longitudinal direction of the fissures indicates that the fracture was occasioned by a direct thrust, which lacked, however, the degree of force necessary to produce a complete fracture. Aside from the bones of the skull, fissures are most frequently seen as a continuation beyond the site of complete fracture of the general lines along which a complete fracture has taken place; under this guise fissures are not infrequent accompaniments of or additions to gunshot fractures.

Green-stick Fractures (Inflexures).—Another form of incomplete or partial fracture is the so-called "green-stick" fracture. To this form of partial fracture the term "infraction" has been rather loosely and carelessly applied. The word "infraction" indicates properly the mode or method by which green-stick fractures are brought about, namely, by a bending or

"buckling" of the bone beyond its limits of elasticity, but its connotation does not imply any indication of the degree of fracture, whether complete or incomplete. A green-stick fracture then is a fracture brought about by the process of "infraction" or bending of the bone, generally by what is termed "buckling," through a direct thrust. It is met most frequently in the forearm and in the clavicle, in either

Fig. 2522.—Fissures of the Cranium.

case a consequence of a fall upon the hand, and it is the common form of fracture of the ribs. It is seen exclusively in children, generally below the age of twelve years. A suitable scientific name for the colloquial "green-stick fracture" would be an "inflexure."

Depressions.—Depressions are fractures involving a limited portion of the cortical layer of the bone which is driven down, always by direct violence, into the spongy layer underneath. Such fractures are seen most frequently in the skull.

Subperiosteal Fractures.—Subperiosteal fractures occur most commonly in the lower end of the femur

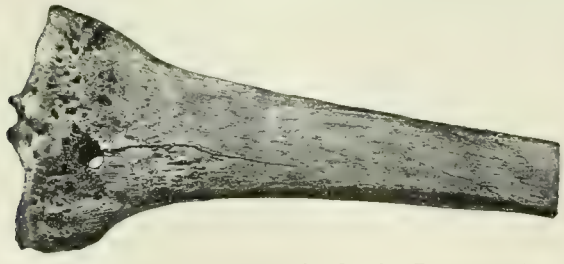


Fig. 2523.—Fissures Accompanying Gunshot Fracture of the Tibia.

and in the lower end of the tibia and fibula, as a complication of a sprained knee or of a sprained ankle respectively. Subperiosteal fracture of the lower end of the femur is especially prone to occur where a limb has been for a long time immobilized, as for hip-joint disease, and a consecutive atrophy of the bone has followed from disuse. Their importance lies in the fact that if unrecognized and if untreated (by

Fig. 2524.—Greenstick Fracture (Inflexure) of the Forearm. (Internat. Textbook of Surgery.)

proper immobilization) throughout a sufficient length of time to allow complete knitting of the bone, such static deformities as knock-knee or flat-foot, of a severe and intractable type, may follow. The lesion is, as the name suggests, a fracture of the bone, usually transverse, without laceration of the periosteum, and consequently with minimal or no displacement of the fragments.

The *x*-ray has demonstrated the occasional occurrence of subperiosteal fractures in the shaft of the long bones.

Separation of a Splinter or of an Apophysis.—The concluding class of partial or incomplete fractures was that involving the separation of a splinter or of an apophysis. Such fractures can obviously occur only about the articular ends of the bones. The splitting off of a splinter, aside from fractures by direct violence, *e.g.* gunshot fractures, occurs, with the single exception of the lower end of the tibia, only as the result of direct thrust in the longitudinal axis of the bone.

Separation of an apophysis, except as included in the splitting off of a fragment as

Fig. 2525.—Fracture of the Ulna, Complete but with Preservation of the Periosteum on the Concave Side of the Angulation. This type of fracture, as there is no displacement but angulation and as the fragments are not movable on one another, is frequently mistaken for a true "green-stick" fracture which is a much rarer lesion. (Drawn from an *x*-ray by Scudder.)

above described, is generally the result of strain on an attached tendon or a ligament. Such fractures are known as avulsion fractures, or fractures "par arrache

Fig. 2526.—Subperiosteal Fracture of the Femur after Atrophy from Long Immobilization. (Case of Dr. C. A. Henze.)

ment." The avulsed fragment frequently carries with it but a thin shell of bone. Common examples are fractures of one or of both of the tuberosities of the humerus and fractures of the tubercle of the tibia.

According to the direction of the line of fracture, fractures, as we have seen, are classed as transverse, longitudinal, etc. A transverse fracture is one where the direction of the line of fracture does not vary more than ten or fifteen degrees from that of the transverse axis of the bone. This variety of fracture is encountered most frequently in the short bones. When it does occur in the shaft of the long bones it is generally the result of "infraction," *i.e.* it is brought about by a bending of the bone beyond its limits of elasticity. Transverse fracture by "infraction" is sometimes seen in the bones of the forearm, under conditions which in children would give rise to a green-stick fracture.

Fig. 2527.—Fracture of the Internal Condyle of the Femur, from a Fall on the Knee. (Stimson.)

Longitudinal Fractures.—Longitudinal fractures belong to the greatest of surgical rarities. They are the exact opposite of transverse fractures, in that they run parallel, or nearly so to the longitudinal axis of the bone; they are caused by a fracturing force acting likewise in a longitudinal direction, *i.e.* by a direct thrust.

Fig. 2528.—Separation of the Greater Tuberosity of the Humerus (Scudder.)

Oblique Fractures.—Oblique fractures are those most commonly seen in the shaft of the long bones. The name alone suffices to define them as intermediate

Fig. 2529.—Spiral Fractures of the Humerus. (After Monk.)

in direction between longitudinal fractures and transverse fractures. They are not commonly caused,

by a single force acting in an oblique direction, after the manner in which transverse fractures are caused by a single force acting in a transverse direction, and a longitudinal fracture is caused by a direct thrust, though this mode of occurrence is occasionally observed in fractures by direct violence, but oblique fractures are generally caused by two forces acting simultaneously, one in a transverse direction (the "shear") and the other in a longitudinal direction (the "thrust"), *i.e.* by the action of a "mechanical couple."

Fig. 2530.—Comminuted Fracture of the Lower End of Humerus from a Fall on the Elbow. (Bryant.)

Spiral fractures are likewise common in the shaft of the long bones. They occur when an element of torsion is added to that of "shear" and "thrust" in the forces occasioning a fracture.

Comminuted Fractures.—Comminuted fractures are those where the bone is broken into more than two fragments, though the term is generally, and properly, restricted to those cases where the lines of fracture are continuous with each other. Where this is not the case and the bone, as occasionally happens, is broken at more than one place and the lines of fracture are not continuous, the lesion is more properly spoken of as a multiple fracture of the bone in question. Comminuted fractures are most commonly caused by direct violence at the point of fracture. When caused, as they sometimes are, by indirect violence, the fracturing force must have been very much more considerable than would have sufficed to bring about a simple fracture at the site of the break. As a rule the degree of comminution is roughly proportional to the momentum of the fracturing force. This application of a great degree of violence, carrying with it almost necessarily a considerable amount of injury to the adjacent soft parts, together with the difficulties attending proper reduction and retention in these cases, makes a comminuted fracture one of much more gravity than one where the bone is broken into but two fragments.

Fig. 2531.—Extensive Comminution of Both Bones of the Leg due to a Runover Accident. (v. Bruns: Bull.)

Impacted Fractures.—Impacted fractures are those where the strong, irregular projecting portions of the cortex of one fragment are driven forcibly into the cancellous tissue of the adjacent fragment. Such fractures are found almost exclusively at the ends of the long bones. From the fact that the cortical layer of the shaft is generally much stouter than that of the articulating ends, it follows that it is generally the portions of the cortex which remain in connection with the shaft that penetrate the spongy portion of the articular extremity, though owing to the frequent angular or rotary displacement of the fragments the cortical portion of the articular end is sometimes forced into the cortical portion of the shaft or into the medullary canal. In fractures of the shaft of the long bones it occasionally happens that the adjacent extremities of the fragments are irregularly serrated or dentated and that these serrations or dentations interlock in a way to offer a great obstacle to reduction,

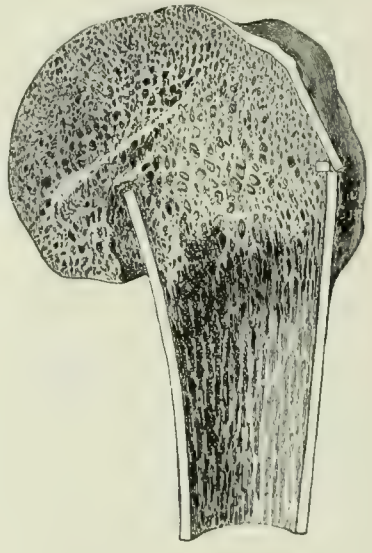


Fig. 2532.—Impaction of the Cortex of the Shaft of the Humerus into the Spongy Portion of the Upper End. (Stimson.)

this is, however, not a true impaction in most cases, as the fragments are not driven one into the other, as the term impaction properly implies. Such a condition of interlocking may be spoken of as a "partial impaction."

Compression Fractures.—Compression and crushing fractures are entitled to a separate clinical classification, though a sharp line of differentiation can perhaps hardly be drawn between them. Compression fractures proper occur chiefly in the tarsal bones from falling or leaping from a height and landing on the sole of the foot, and in the upper part of the humerus from a direct blow upon the shoulder.

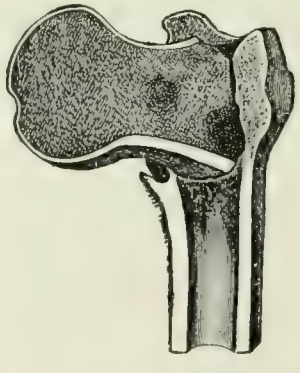


Fig. 2533.—Impacted Fracture of the Base of the Neck of the Femur. The resistant arch of Adams is driven into the trochanteric mass till it impinges on the external cortical layer. (Stimson.)

Fig. 2534.—Compression Fracture of the Shoulder. The mass of the tuberosities is driven like a wedge into the spongy bone by a fall directly on the shoulder. This is an example of Y-fracture. (Bryant.)

Crushing Fractures.—Crushing fractures, on the other hand are not limited to any part of the skeleton. They are caused by the impact of massive and heavy

bodies, compressing the bones against the ground or against some other massive body. Such injuries are seen in railway accidents, and particularly in naval warfare, they result from accidents about heavy machinery and in being run over by cartwheels or heavy vehicles. Their extreme form, in which a

Fig. 2535. Crushing Fracture of the Os Calcis. (Drawing from *x*-ray figure by Scudder.)

limb is completely severed from the body, is known as a "traumatic amputation." From this the scale descends to the crushed fingers caught in drop-presses of the lighter type, and blows upon the finger with a hammer. The degree of comminution in these fractures is often extreme, and the grave injury to the adjacent soft parts often precludes any reasonable treatment short of amputation. A well recognized attribute of injuries of this description is the extreme degree of "shock" which generally attends them.

Epiphyseolysis.—Epiphyseal separation (epiphyseolysis) can occur only during that period of life when the epiphyseal cartilages are still extant, and, furthermore, we may judge from available statistics that this lesion is unlikely to occur until the period when the epiphysis itself has undergone tolerably complete ossification. During infancy and early childhood, up to about the eighth year, the epiphyses together with the

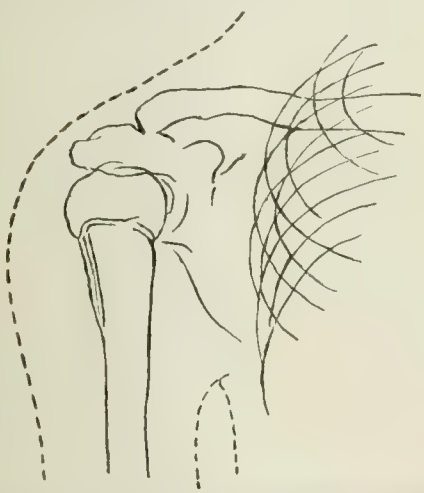


Fig. 2536.—Separation of the Upper Epiphysis of the Humerus, the Most Common Epiphyseolysis. Note the cup-shape of the epiphysis and the somewhat pointed end of the diaphysis. Note also the periosteum attached posteriorly. (After a sketch by Cotton from an *x*-ray.)

epiphyseal cartilages form so elastic and yielding a mass that their fracture and separation from the diaphysis are rarely observed. After the age of twenty-one years the epiphyses are all so firmly consolidated with the diaphyses that epiphyseolysis becomes an impossibility, save in some exceptional cases of delayed ossification. The separation of an epiphysis is analogous to a transverse fracture of the bone, but to a transverse fracture where a transverse line of lessened resistance permits of a transverse fracture under conditions which in the adult bone would give rise to an oblique or to a spiral fracture. This form of fracture is produced either by a force acting transversely or by a shear and a thrust, where the element of shear considerably predominates. Although the line of such fractures follows substantially the junction of the epiphyseal cartilage with the diaphysis, yet it is quite exceptional to see a clean separation in this plane; much more frequently an irregular fragment of the diaphysis will be torn away and will maintain its connection with the epiphysis.

Intraarticular Fractures.—Articular fractures are divided into intraarticular fractures, juxtaarticular fractures and articular fractures proper. An intraarticular fracture is one in which the line of fracture lies entirely within the joint capsule. Such fractures may be produced by a direct blow upon the region of the joint or by direct thrust of moderate severity when the thrust is combined with a certain element of torsion. Such fractures may have been originally incomplete separations of superficial chips of the articular surfaces, *i.e.* mere fissures loosening up rather than completely detaching a scale of bone covered with articular cartilage. Later on, a slowly progressive rarefying osteitis (osteitis dissecans) along the course of the fissure inaugurated by such a trauma, the mild inflammatory process being essentially due to lack of immobilization and of sufficiently protracted rest after the original injury, is considered by competent observers to be, in many cases, responsible for the loosening of these bony fragments from their bed. The knee-joint is not infrequently the site of intraarticular fractures of this description, and their importance lies in this, that the fragment separated from the femoral condyle, or less frequently from the tibial head, may fail to become reunited to the rest of the bone, and may eventually become displaced from its proper relations and become loose within the joint-cavity as a free foreign body, called by the Germans a "Gelenkmaus." When removed by operation, the loose bodies are often found to correspond roughly in shape with obvious defects in the articular ends of the adjacent bones. The occasional occurrence of such free foreign bodies, distinct in nature from the so-called "rice-bodies," which have been shown to be due, for the most part to an infectious (generally a tuberculous) process in the synovial fringes, in the elbow and rarely in still other joints of the body, indicates that all these several joints are obnoxious to intraarticular fractures. Two facts are worthy of notice with regard to these singular fractures. First, the amount of trauma required to initiate the process of the formation of free foreign bodies within the joints is often very inconsiderable, so slight in fact as in many cases to escape the memory of the patient. Secondly, an interval, commonly of months, sometimes of years may elapse between the receipt of the trauma and the appearance of the so-called "internal derangement" of the joint.

Juxtaarticular Fractures.—Juxtaarticular fractures are those where the line of fracture runs in close proximity to the joint, but does not trespass upon it. The commonest cause of these fractures is forced extension or forced flexion of a ginglymoid joint. Their special importance lies in the difficulties of reposition and retention of the fragments and in the interference with joint function which follows even a moderate degree of malunion.

Articular Fractures Proper.—Articular fractures, properly so called are such as have a line of fracture partly within and partly without the joint capsule. These fractures are much more common than either intraarticular or juxtaarticular fractures. The opening of the joint capsule of itself adds considerably to the severity of an articular over a juxtaarticular frac-

ture, because the joint effusion is more considerable and is of a hemorrhagic character, making it more difficult of absorption than the simpler joint effusion attending a juxtaarticular fracture; there is also greater liability to contracture of the capsule, which in articular fractures is rent and lacerated instead of being merely stretched or strained, and such capsular rents and lacerations are apt to heal with disabling cicatricial contractions hindering greatly the proper movements of the joint. These disadvantages pertaining to articular fractures, to which must be added the same difficulty in the fixation of small fragments, which is present in juxtaarticular fractures, are very considerably increased when the line of fracture not only enters the joint cavity, as delimited by the capsule but actually crosses a part of the articulating surface. In this case there is a coincident fracture of the articular cartilage and this is accompanied with a certain loss of substance which is never filled in with cartilaginous material, and this cleft in the cartilage will always remain as an unevenness in the joint which will correspond with some reciprocal deformity on the opposed articular surface. The most important sequel of articular fractures, is however, the manner in which want of proper alignment of the fragments, even if slight, will interfere with the proper play of the joint. On this account it is always well, when we cannot be sure that we have secured exact reposition, to adapt the position of the fragments to the requirements of the joint by passive motion instituted before full consolidation of the bone has taken place, and earlier than we should ordinarily commence it in other classes of fracture.

Pathological Fractures.—Fractures are divided according to their etiology into pathological (spontaneous) fractures, fractures by muscular action, and fractures by external violence (traumatic fractures).

A pathological fracture is one which is caused in bones which are wasted by intrinsic disease, eroded by the pressure of an aneurysm or substituted by the cells of a neoplasm, by such minimal external violence, as for instance turning over in bed, that the fracture may appear to be spontaneous. It is noteworthy in regard to many of these pathological fractures that they take place almost or quite without pain.

Fractures by Muscular Action.—Fractures by muscular action are rare, with the exception of fractures *par arrachement* (avulsion fractures) which are met not very frequently in the patella, the olecranon process of the ulna and the tuberosities of the humerus, of the tibia and of the os calcis. They occur generally as the result of the torsion of a limb against resistance. The humerus offers more than twice as many examples of fracture by muscular action than all other bones of the body together.

Fractures by Direct Violence.—Fractures by external violence (traumatic fractures) are divided into fractures by direct and by indirect or transmitted violence.

In fractures by direct violence the fracturing force impinges directly upon the bone, being modified in its effects by the more or less substantial and elastic intervening cushion of soft parts. There are certain phenomena which fairly regularly characterize these fractures. In the first place the fracture will occur directly at the place where the force is applied; secondly such fractures occur most often where the overlying soft parts are thin, *e.g.* the head of the humerus, the shaft of the tibia or of the ulna; thirdly, such fractures are almost invariably comminuted fractures, and the degree of comminution is sensibly proportional to the momentum of the fracturing force at the point of impact.

A direct force, when of moderate intensity, impinging on the shaft of a long bone, in a plane perpendicular to its axis, occasions a very characteristic fracture of the underlying bone, tending to the type represented in Fig. 2537 where a wedge-shaped piece is burst out of the shaft of the bone, with its base at the region of impact and its apex away from the same. With greater force applied this wedge tends to break up into subsidiary wedges having their bases toward and their apices remote from the region of impact. This, be it noted, is only the type which these fractures tend to assume, the varying thickness and strength of different portions of the cortex, the nearness of the epiphyseal cartilage, of the nutritive and other foramina, as well as many other factors will of course influence the lines of fracture. Nevertheless, these will, be it again emphasized, be almost invariably multiple and will show characteristic cuneiform fragments.

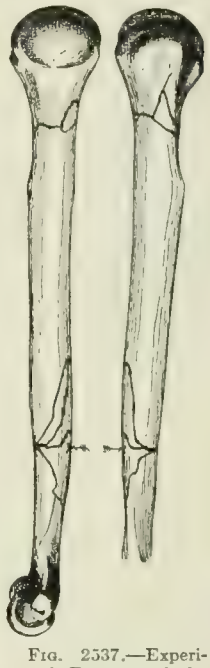


Fig. 2537.—Experimental Fracture of the Shaft of the Humerus by Direct Violence. Note the great degree of comminution and the fissures extending up and down the shaft of the bone. (Kocher.)

This tendency to multiple comminution becomes still more marked when the momentum of the direct violence is greater, as in gunshot fractures, though the high-velocity modern jacketed rifle-ball, at medium ranges may perforate without fracturing the bone.

Though it is not our purpose to treat particularly of gunshot fractures, we may point out here that a portion of the momentum of the original missile is imparted to each of the subsidiary fragments in a gunshot fracture, and that each fragment may act, to a certain degree, as a "secondary missile," tearing its way along divergent lines, thereby occasioning the extensive laceration and pulpification of the adjacent soft parts which are characteristic of these gunshot lesions. It is in part the action of these "secondary missiles," along lines divergent from the point of impact, which causes the wound of exit of a perforating gunshot wound to be so much larger and more considerably lacerated than the wound of entrance.

The remaining forms of fracture by direct violence, namely, compression fractures and crushing fractures have already been defined and described in considering the classification of fractures according to the direction of the line of fracture.

Fractures by Indirect Violence.—The five classes into which fractures by indirect or transmitted violence were divided were (1) fractures by direct thrust; (2) fractures by avulsion or *par arrachement;* (3) fractures by torsion; (4) infractions or fractures by bending; and (5) fractures by leverage.

Fractures by Direct Thrust.—Fractures of the long bones by direct thrust have one distinguishing characteristic, namely, that the line of fracture is quite constantly nearly parallel in direction with the line of action of the force causing the fracture. The line of cleavage will be very slightly oblique and the fragments will have the common and characteristic shape of rather long

Fig. 2538.—Intercondylar Fracture of Femur by direct Thrust. Note the slight obliquity of the lines of fracture. (Stimson.)

and rather thin wedges, ending in a sharp thin edge or point.

Avulsion Fractures.—Fractures by avulsion or *par arrachement*, with the exception of a considerable proportion of fractures of the patella, are limited to the tearing off of certain bony apophyses through violent traction upon their attached ligaments or tendons. Such a fracture can the more easily occur when the traction upon the ligament or tendon is in an unusual and unaccustomed direction, such as is exerted upon the lateral ligaments of a ginglymoid joint under forced adduction and abduction of a limb which is adapted only to anteroposterior flexion and extension. Another fact is noteworthy in this connection, namely, that when a breaking strain is put upon a tendon proper, the strain is more likely to cause an avulsion fracture of the apophysis to which the tendon is attached than it is to rupture the tendon itself; when, on the other hand, the tendon is expanded into a broad band-like aponeurosis the strain is likely not to pull true upon all the aponeurotic fibers simultaneously, but to exert a superior stress upon one edge of the aponeurotic band, which edge yielding allows the strain to be exerted upon successive sets of fibers, piecemeal, so that a rent is started in the aponeurosis which may be completely ruptured by a force which would be inadequate to rupture a compact, quasicylindrical tendon of much smaller sectional area. In a true avulsion fracture the amount of bone is usually very small, sometimes a mere scale at the tendinous insertion; where a larger fragment is carried away there is generally some other force in play besides a straight away tug.

Fig. 2539.—Avulsion of the Internal Epicondyle of the Humerus Note small size of fragment. (Helferich.)

Fractures by Torsion.—Fractures by torsion are generally modifications of fractures by direct thrust or of fracture by leverage, where a certain torsional moment is combined with the simple direct thrust, or with the thrust and the shear of a fracture by leverage. Fractures by torsion result in a spiral line of fracture. These spiral lines of fracture the result of torsion are seen exclusively in the shafts of the long bones, most often the humerus, owing to the wide leverage afforded by the expanded ends of that bone and the slenderness of its shaft; but not infrequently in the tibia and in the femur. The bone in these fractures presents long, spiral fissures, with or without complete separation of the fragments. With increase in the momentum of the fracturing force goes an increasing probability of comminution, in which case the fragments are prone to have a spiral curve along both their upper and their lower edges indicating the development of two parallel spiral lines of cleavage.

Fig. 2540.—Spiral Fracture of the Shaft of the Left Femur through a Fall on the Foot with Leg extended. Note that the spiral is a right helix. This is due to the forcible eversion of the foot. A similar force applied to the right limb would have given a left helix. There is likewise an impacted fracture at the base of the femoral neck. (From a specimen in the Mass. Gen. Hospital.)

Infractions (Inflexures).—Infractions, or fractures by bending, are relatively infrequent. In infractions, the tendency is for the line of fracture to be pretty nearly transverse, though the tendency to the separation of a cuneiform fragment on the concave side, *i.e.* at the point of application of the force, is sometimes observed. These transverse fractures, with the exception of separations of the epiphyses, are rare; the circumstances under which they may occur make it unlikely that they will be encountered outside of the middle third of the long bones, and as a matter of fact the tibia, the femur, the humerus and the bones of the forearm are those where infractions, with their characteristic transverse fracture line, are most frequently seen; with the exception of the ribs, where, save for direct violence, infraction is the commonest form of fracture. It should be added here that "green-stick fractures," or "inflexures" are generally caused by infraction or bending of the bone beyond its limits of elasticity, and that their method of production is as described for infractions. The occurrence of "green-stick" fractures of the ribs has already been noted above and is in consonance with this mode of production.

Fractures by Leverage.—The commonest and the most important mode of the transmission of a frac-

turing force is by leverage exerted through the joint ligaments, with the distal portion of the limb acting as the "power arm," and some portion of the articular end of the bone acting as "fulcrum" or as "weight." A force which is transmitted to a bone by leverage can in all cases be resolved into two components, one component acting parallel with the axis of the bone; this we call the "thrust," and a second component acting perpendicularly to that axis, *i.e.* transversely across the bone, this component we call the "shear." Upon these two moments, the thrust and the shear, all fractures by leverage depend.

The element of leverage in the causation of a fracture is invariably shown, except only in the case of epiphyseal separation, by the obliquity of the line of fracture; in other words, fractures by leverage are always oblique fractures. It is a general rule in fractures by leverage that the actual cleavage of the bone begins at the point where the "shear" first becomes effective, while the sense in which the line of fracture shall depart from a directly transverse direction will be determined by the direction of the co-operating "thrust," the degree of obliquity of the line of fracture being determined by the relative magnitude of the "shear" and of the "thrust" respectively. The appreciation of the mechanical factors involved

Fig. 2541.—Fracture of both Bones of the Leg by Infraction. Note that both fractures are substantially transverse and that both show a cuneiform fragment on the concave side, a frequent occurrence in fractures by bending. (Helferich.)

in fractures by leverage is naturally simplest in fractures near the ginglymoid, or hinge joints. These joints permit of motion in but two directions, that is flexion and extension, and fractures by leverage in the neighborhood of these joints are generally produced by an excess of motion in one or the other of these directions, yielding two types of fracture known as "extension fractures" and "flexion fractures" respectively.

Complementing Categories.—It will not have escaped the reader's observation in this review of the different classes of fractures, how completely the category of fractures classified according to their etiology complements and dovetails into the category of fractures classified according to the direction of the

Fig. 2542.—Supracondylar Fracture of the Humerus by Hyperextension. (Stimson.)

Fig. 2543.—Flexion Fracture of Humerus; Supracondylar. (Stimson.)

line of fracture. Indeed, it may somewhat summarily be said that transverse fractures are produced by infraction, longitudinal fractures by direct thrust, oblique fractures by leverage, spiral fractures by torsion, comminuted fractures by direct violence, while compression fractures and crushing fractures are but the names given to fractures effected by compressing and by crushing forces acting on the bone. There is one important inference to be drawn from this observed complementing of one category of fractures by the other, namely this, that the vulnerating forces continue to act on and in the bones in the direction in which they are originally brought to bear, until the several forces are dissipated or are deflected from their line of action by other associated forces. Owing to this general principle of mechanics we can, to a considerable degree, regard these two categories of fractures as virtually reciprocal, and within certain limits we may say that the rule will hold good that transverse fractures are produced by infraction and by no other means, and reciprocally that infraction will produce a transverse fracture and no other, in the same way it is fairly accurate to state that all oblique fractures are produced by leverage, and that all fractures by leverage will be oblique. The reasoning, which may seem to be but a playing on words, may, in certain medicolegal cases, acquire a considerable importance, as tending to demonstrate how a given bone injury could, or must, have been received.

Closed (Simple) and Open (Compound) Fractures.—The next category of fractures we have to consider has to do with their classification according to their relation to the overlying skin, into open and closed fractures. An open fracture is one where the line of fracture communicates with a wound in the skin or, as in fractures of the base of the skull, of the bones of the face and of the jaw, with a mucous membrane. A closed fracture is one which does not so communicate. The importance of this classification lies of course in the opportunity for infection of the bone, with the attendant dangers of sepsis of a peculiarly formidable type. There are two reasons why grave infection so readily follows open fractures, first, an open fracture is generally caused by great violence, involving extensive laceration and relative devitaliza-

tion of the tissues adjacent to the fractured bone, and these lacerated and devitalized tissues offer but a feeble resistance to infectious agents; secondly, when infectious agents once gain access to the medullary canal of the long bones, the medullary tissue, showing, instead of a fully developed vascular organization, only a survival of the more primitive form of lacunary circulation, such as is seen in the lowlier forms of the mollusca—this tissue is unable to erect the wall of circumvallation which constitutes so effective a barricade against the advance of infectious processes in the more highly vascularized portions of our anatomy. For this reason the operative treatment of fractures by the so-called "open method" should never be undertaken except where the strictest asepsis can be secured.

Single and Multiple Fractures.—The sixth category of fractures had reference to the number of fragments into which a bone is broken, and to the number of bones which are fractured. The terms defining this category of fractures are single fractures and multiple fractures. A single fracture is one where a single bone is fractured at but one place, even if the bone is comminuted at the seat of the fracture. The term multiple fracture, as applied to a single bone, is used only where the lines of fracture at one part of the bone are not continuous with those at the other broken portion. The term multiple fracture is also used to designate fractures in more than one bone provided the two bones do not lie parallel in the same limb. In technical parlance a simultaneous fracture of the tibia and fibula, or of the radius and ulna, is not denominated a "multiple" fracture but is spoken of as a "single" fracture of the leg or of the forearm, "involving both bones." Multiple fractures of the leg and of the forearm are, indeed, occasionally seen, but if the term is used properly this would imply fractures of the limb at two different heights.

Complicated and Uncomplicated Fractures.—The final division of fractures, in the system of classification we have adopted, is into complicated and uncomplicated fractures. A complicated fracture is one where some adjacent structure of importance is involved in the injury which caused the fracture. In fractures of the limbs the term "complicated fracture" would imply injury to an adjacent joint, or to important ligaments, nerves or blood-vessels; in fractures of the ribs, of the pelvis, of the hyoid bone or of the sternum, the term would imply injury to a viscus, or to the serous membrane; in fractures of the skull and of the spinal column the injury to the inclosed nervous structure so far transcends in importance the fracture of the bone that we shall not attempt the study of these fractures in this article. General and constitutional complications, such as sepsis, pneumonia, nephritis and the like, are not properly included in the term complicated fracture. An uncomplicated fracture, it is needless to say, is one in which the special and local complications we have enumerated do not exist. Special forms of complicated fractures have received special descriptive names such as "fracture-sprains" and "fracture-dislocations," indicating that the gravity of the injury is shared between the fracture and the complication.

DISPLACEMENTS. *The Causes of Displacements.*—Closely allied to the subject of the classification and definition of fractures is that of the classification and definition of the displacements of the fragments which take place when a bone is fractured. Fissures, subperiosteal fractures and a large proportion of intra-articular fractures show no displacement, and the same is occasionally true of complete fractures, even of the shaft of the long bones, most frequently in fractures of a single bone of the forearm or of the lower leg, where the remaining unfractured bone acts as a splint. Displacements are brought about in four ways, first, by the continued action of the primary fracturing force; this is seen most conspicuously in fractures by leverage; secondly, by the action of the muscles attached to the broken bone; this is seen in a large proportion of fractures of the shaft of the long bones, *e.g.* in subtrochanteric fracture of the femur the iliopsoas muscle, attached to the lesser trochanter, brings the upper fragment almost invariably into a position of flexion more or less modified by the action of the pelvic muscles attached to the upper part of the femur, which are mostly abductors and external rotators; thirdly, by the weight of the limb, notably in fractures of the clavicle, where the weight of the limb is an important factor in causing the acromial end of the bone to be carried downward, forward and inward; fourthly, what is called "secondary displacement" occurs from active efforts of the patient to move after the fracture, from movements imparted to the injured limb in transporting the patient and from unsuccessful efforts to reduce the fracture.

The diagnosis as to what particular displacement is present in a given case, often a matter of great difficulty, is many times greatly affected by the light thrown upon the case by an accurate inquiry regarding these four points, viz., the nature and direction of the force by which the fracture was produced, an intimate knowledge of the play of the muscles attached to the displaced fragment, the influence of gravity upon the injured limb and the probability of "secondary displacement" from active movements of the patient, from the effects of transportation of the patient or of his extrication from wreckage, and from previous efforts at reduction.

The Modes of Displacement.—The recognized modes of displacement are six in number: lateral displacement, angular displacement, rotary displacement, impaction, and two forms of longitudinal displacement, overriding and diastasis.

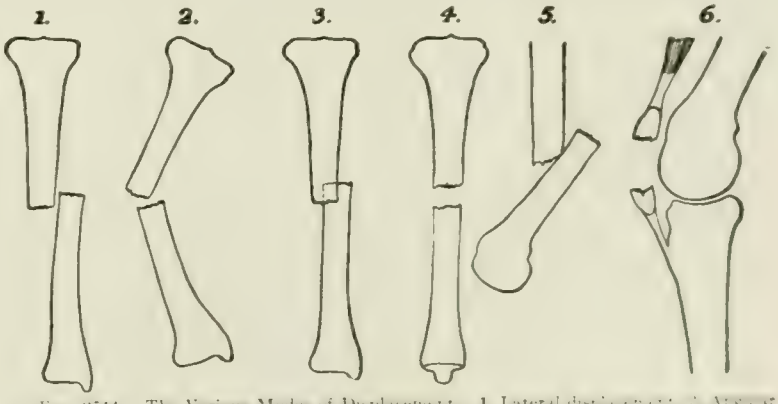


FIG. 2544.—The Various Modes of Displacement. 1, Lateral displacement; 2, Angular displacement; 3, Overriding; 4, Rotary displacement (note that the [illegible] as indicated in the preceding figures as at the side, is shown in inward rotation); 5, Overriding and angular displacement combined; 6, Diastasis. (Keen.)

Lateral displacement may occur in a forward or backward direction or toward either side. In its simple form the longitudinal axis of the two fragments would lie in lines which are substantially parallel but which are separated from one another by the amount of the displacement. Such a displacement is occasionally seen in the shaft of the long bones where the line of fracture is nearly transverse or where the fragments present serrated and interlocking den-

tations, also in fractures of the forearm or of the lower leg where one bone remains intact. Like the other forms of displacement, lateral displacement is rarely seen alone, but is ordinarily combined with one or more of the other forms, angular, rotary, or longitudinal.

Angular displacement varies from a slight inclination, commonly seen in the forearm or the lower leg, to an inflexion of ninety degrees, or even more, occasionally encountered in the thigh and the upper arm, where the skeleton of the limb has but a single bone for its support.

Rotary displacement, while most common and most marked in those parts of the limbs which have but one bone, is also found with some frequency in fractures of the shaft of the radius, owing to the peculiar function of that bone in the office of pronation and supination of the hand.

Impaction has already been described in discussing impacted fractures.

The first form of longitudinal displacement, namely overriding, is generally the result of muscular action; on this account it is most frequently observed where the limb has but a single bone, and is most pronounced and troublesome where the muscles are longest and most powerful, as in fractures of the femur. It is specially liable to occur where the fracture is oblique.

The second form of longitudinal displacement, namely diastasis, is always the result of muscular action, save in such cases as are virtually the spreading of a fissure, as in fractures of the skull, where the broken edges of the fractured cranium may gape to a considerable degree. With this exception diastasis occurs only in fracture of the patella and in separation of the various apophyses.

In partial fractures the same descriptive terms are applied to the displacement of the fragment as are used in the description of complete fractures.

General Principles Governing The Mechanics of Fracture.—Before we proceed to take up the subject of special fractures there remain a few words to add concerning three general principles to be considered in diagnosticating fractures, both those by direct and those by indirect violence.

Of these general principles the first is that increased momentum in the fracturing force means increased tendency to comminution. We have already shown that this is true in fractures by direct violence, it is no less true of fractures by indirect violence. As examples we may mention so-called Y-fractures of the upper end of the humerus; these fractures may be caused by direct violence applied to the shoulder, or they may be brought about by leverage exerted through the arm; in either case a greater degree of violence is required to produce a Y-fracture than to produce a simple pertubercular fracture of this bone. A T-fracture above the condyles of the humerus requires greater force than fracture of the external condyle by direct thrust, or than simple supracondylar fracture whether by extension or by flexion. Fracture of the articular surface of the lower end of the tibia as a complication of Pott's fracture demands more force than the commoner fracture of the fibula with avulsion of the internal malleolus; when this complication does occur it implies a great preponderance of thrust over shear and it is to be expected in a false landing from a jump, rather than in mere tripping with the foot caught in an obstruction. The recognition of this principle is important because if the history shows the evident absence of greater violence we may conclude that the greater comminution is not likely to be present. Recognition of this principle alone will allow us, almost with certainty, to differentiate, in many cases, between fracture and dislocation of the hip; slight force will suffice to fracture the senile femur, very great violence is necessary to bring about dislocation of the hip.

The second general principle we allude to is that any force applied to the body becomes dissipated as it advances. This is seen particularly where a fracturing force is transmitted by direct thrust, and accounts in great measure for the fact that fracture at the junction of the middle and outer thirds of the clavicle is very much more common than fracture at the junction of the middle and inner thirds, also for the fact that in fracture near the knee by direct thrust, through falling from a height and landing on the feet, it is much more commonly the upper end of the tibia that presents the long, slightly oblique fissures typical of this kind of fracture, than the lower end of the femur, indeed the whole skeleton of the body is designed, with its multiple articulations, its interposed articular and intra-articular cartilages and the curved rather than straight shafts of its bones, to dissipate the various shocks which the frame of our bodies may receive from externally applied violence.

The third general principle is that mechanical forces continue to act in the same direction in the bone that they were pursuing before their action began upon the bone, thus a longitudinal force, a direct thrust, tends to evoke longitudinal cleavage; a transverse force, infraction, a transverse cleavage; a spiral force, torsion, a spiral cleavage, etc.

The Repair of Fractures.—The repair of fractures may be described as consisting of three stages, of which the first includes as essential phenomena the formation of a primary hematoma with coagulation of the effused blood and the establishment of an inflammatory edema.

The second stage includes the formation of vascular granulations throughout the focus affected by the trauma and the proliferation of the cellular elements of all the tissues involved; in this cellular proliferation the bone cells are reproduced more tardily than are the cells of the muscular and connective tissues. These bone cells are of three orders: first, those derived from the periosteum, which proliferate most freely and most promptly, and revert to their embryological type of cartilage cells before becoming converted into true bone tissue; secondly, the cells from the medullary tissue, which form bone directly, and serve to build up the so-called medullary plug, which completely fills the medullary canal of both fragments; and thirdly, the bone cells which sprout very tardily from the compact cortical layer between the periosteum and the medulla. The large, somewhat ovoid cellular mass, containing connective-tissue cells, muscle cells, new formed blood-vessels and bone cells of all three types, constitutes the so-called provisional callus. The formation of the provisional callus is generally complete toward the end of the third or fourth week and marks the completion of the second stage of repair.

The third stage is practically one of cicatrization, in which the process of phagocytosis and absorption of superfluous reparative material is paramount; such new formed blood-vessels as are not requisite for the normal nutrition of the parts become obliterated, the inflammatory edema subsides, and the connective tissue and muscular cells lose the rotundity and succulence which are characteristic of their embryonic stage and take on their more wonted aspects, while a similar metamorphosis goes on among the bone cells, whose intercellular matrix becomes again impregnated with calcium salts lending the requisite rigidity to the hitherto soft pliable callus. At the time when lime salts begin to be deposited about the bone cells the mass of the callus has already shrunk considerably in size and has acquired a marked degree of firmness, and the tissues surrounding the fractured bone have proceeded considerably further than has the osseous tissue itself toward a complete return to the normal; the callus therefore, at this stage appears to be confined more exclusively to the bone proper and is spoken of as the permanent, as the definitive, or as the bony callus. The process of phagocytosis has in reality been going on from the beginning. The re-

moval of the débris of the injured soft parts is the peculiar office of the leucocytes and of the microphages and the macrophages which invade the injured focus from without or are derived from the immediately circumjacent tissues. The removal of detached fragments of bone, or of projecting and useless spicules is, however, the special office of the osteoclasts, large plasmodial cells derived probably from the medullary tissue, which apply themselves to such bony masses as are destined to absorption, and by the specific solvent power of their cellular secretion divest such bone fragments of their lime salts and cause their ultimate disappearance. The action of the osteoclasts continues after most of the rest of the reparative forces have subsided, until, after a period of some months, all sharp bony projections have been rounded, off and the continuity of the medullary canal, which was temporarily filled with the cells of the medullary plug, has been restored.

The normal reparative processes in bone may be perverted by want of correlation of the respective factors. Thus the process of phagocytosis may be excessively active, resulting in an undue absorption of the ends of the fragments and it is suspected that the excessive action of the osteoclasts may also cause a redissolving of the freshly formed callus. Excessive production of callus is often seen where there is defective immobilization, and defect of the periosteum or overriding of the fragments may suppress the proper formation of burgeons from one or more of the three classes of bone cells, which should by right all participate in the furnishing of the reparative cellular material.

Diagnosis.—*The Cardinal Signs of Fracture.*—The diagnosis of fractures depends on the proper recognition and appreciation of the subjective and the objective signs. The cardinal subjective signs are three, pain, tenderness and loss of function; and the cardinal objective signs are also three, deformity, abnormal mobility and crepitation.

The pain in fracture is ordinarily immediate, acute and greatly aggravated by motion of the injured parts, which unless they are firmly supported by splints are thrown into motion, despite the efforts of the patient to keep them quiet, by involuntary muscular contractions. The pain is ordinarily referred to the seat of the fracture, but may be referred to the area of distribution of some passing nerve.

The tenderness is generally susceptible of more definite localization and constitutes one of our most valuable guides to the exact seat of the fracture, as the point of maximum tenderness is ordinarily over the ends of the fragments. A well recognized diagnostic rule is the following: When pressure applied laterally or in the long axis of a bone evokes pain at a distance from the point where the pressure is applied there is a fracture at the painful point.

Careful study of the residual function in a limb after fracture will often show that its abolition is not so complete as might be supposed, and careful attention should be given to the determination of the residual function, with effort on the part of the surgeon to calm the fright and nervous apprehension of the patient during the investigation, so as to bring out as fully as possible such elements of function as still remain.

The word deformity as a sign of fracture is used in its broadest sense and includes abnormalities in the contour, in the axis and in the length of the affected member. The chief deformities in the contour of a member will be due to the swelling, which in a recent fracture is in large measure the result of the hemorrhage and of the inflammatory edema, these must be gauged chiefly by inspection and by palpation.

Further elements in the disturbance of contour will be due to the abnormal protrusion of normal bony prominences, or to the absence of normal bony prominences, or else to the appearance of bony projections which are abnormal and are a portion of a displaced fragment. These points must be determined largely by palpation.

Axial deviations call for a practiced eye for their proper appreciation. When they are but slight the projection of the axis by means of a taut string or of a straight rod will make a slight axial deviation somewhat more easily appreciable.

Discrepancies in length between the injured member and its uninjured fellow are of the highest importance in the diagnosis of fracture. To determine such discrepancies it is essential that the two limbs which are to be compared should be placed with great accuracy in exactly symmetrical position, failing which the results of mensuration may be very misleading. In fractures of the femoral neck with partial impaction it is not uncommon to find but a minimum of shortening in the first hours after a fracture and to find the shortening much more pronounced at a subsequent examination.

Abnormal mobility is a most important sign of fracture. It is of particular service in juxtaarticular fractures in determining the exact nature of the fracture. A good illustration is in the fractures of the lower end of the humeral shaft. In supracondylar fracture there will be hyperextension, adduction and abduction; in fracture of the external condyle alone there will be slight hyperextension and abnormal adduction but abduction will not be possible to any considerable degree; in fracture of the internal condyle there will be marked hyperextension and marked abduction, but adduction will be much less pronounced. Fracture of the shaft of a long bone will give not only mobility in abnormal degree and direction but will give also the phenomenon of mobility at an abnormal site, which is naturally less conspicuous when the fracture is in the neighborhood of a joint.

Crepitation is caused by the rubbing together of the broken bone surfaces, if of the true bony variety it is pathognomonic of fracture, but it is absent in impaction and in diastasis and frequently fails to appear when expected. Its determination is rarely essential to the diagnosis, and except in cases otherwise doubtful, it is rarely wise to seek it specifically, though it should always be given its full diagnostic value when it is developed incidentally to other investigations.

One objective sign of fracture which, though it does not deserve to rank as one of the cardinal signs is yet often of great importance, is the appearance of ecchymosis without contusion. Such ecchymoses may appear from twenty-four to sixty hours after an injury in which fracture was not suspected, their appearance should be an indication for a careful revision of the diagnosis with the question of fracture distinctly in view, as they of themselves afford strong presumptive evidence of the existence of bone fracture.

The *x*-ray when available should be used to confirm a diagnosis; this, however, should be determined as exactly as possible beforehand by a careful study of the subjective and objective signs. Where its cost or inconvenience makes the use of more than one session inadvisable, the most advantageous time to use the *x*-ray is after the best efforts of the surgeon have been made toward reduction and fixation. In hospital work, free use of the *x*-ray is a vast help both in diagnosis and in the adjustment of fractures.

Treatment.—The treatment of fracture consists essentially in reduction and in immobilization of the reduced fracture throughout a period sufficient to permit the bony fragments to become sufficiently firmly united to prevent further displacement. When such a degree of fixation has been obtained the sooner all restraining apparatus can be removed, the more prompt and more perfect will be the restoration of function.

The special means to this end will be more fully considered under the portion of this article which deals with special fractures. Where it is applicable one of the most satisfactory methods of immobilization and one which will give most relief to the pain of fracture is continued traction by properly adjusted weights and pulleys. When this method can be employed a formal reduction of the fracture is often not

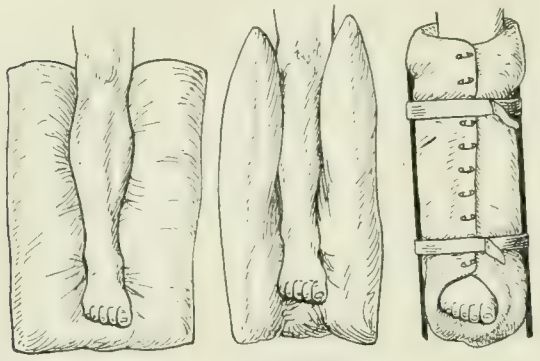


Fig. 2545.—Fractured leg Supported in "pillow-roll." Further support given by lateral splints.

required, as the fragments fall into their proper relations through the axial traction.

Properly padded board splints are very generally useful for such cases as do not admit of treatment by continued traction. For fractures of the lower leg plaster-of-Paris encasements are very widely used, but most such fractures are best treated for a sufficient time to allow the subsidence of primary swelling, in a pillow-roll or in a fracture-box filled with sand bags.

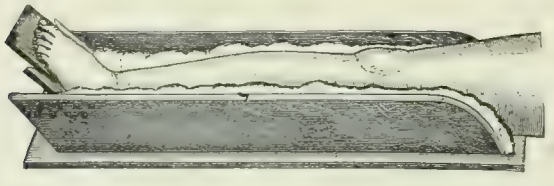


Fig. 2546.—Fracture-box.

In fractures of the upper arm and of the thigh short coaptation splints, three or four in number may be advantageously applied snugly to the limb by means of adhesive strips, they are not intended to support the limb as a whole but only to restrain the fragments from lateral displacement, and should therefore not be long enough to bear upon the bony prominences near the articular ends of the femur or of the humerus. Supporting splints, in contradistinction to coaptation

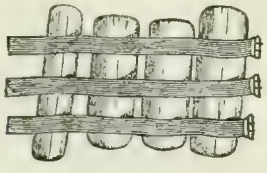


Fig. 2547.—Coaptation Splints for Application to Femur.

splints, should be long enough to include at least one joint either above or below the fracture, and where this does not occasion too great inconvenience, to include both the superior and the inferior joint.

But few special splints are required in the treatment of fractures, the large variety of devices of this description which were in use before the days of plaster of Paris and of adhesive plaster extension apparatus being now almost universally discarded. Such special apparatus as some few fractures require will be considered in describing the treatment of special fractures.

Modern advances in surgery have made possible the more frequent application of open operation and direct fixation of the fragments in the treatment of fractures. Particularly in the treatment of spiral and of very oblique fractures and in the treatment of comminuted fractures, the use of bone plates and screws is widely advocated, but their use demands the most scrupulous asepsis for success, and where the experience of the surgeon and the surroundings of the patient do not make this condition an assured fact the practice is likely to be not only disappointing in its results, as far as bone fixation is concerned, but dangerous to the patient as well.

A greater advance in surgery than the use of bone plates and screws lies in the more recent use of autogenous bone grafts, which have had their greatest success in the treatment of ununited fracture and in the substitution of actual bone defects. Here, too, a most rigorous aseptic technique is indispensable to success, but with this condition supplied the results have been most highly gratifying. For the details of technique other articles in this work must be consulted.

Special Fractures.

Fractures of the Bones of the Face.—Fractures of the nasal bones, of the superior maxilla and of the malar bone and the zygoma are all of them the result of direct violence; in all of them there is a similar

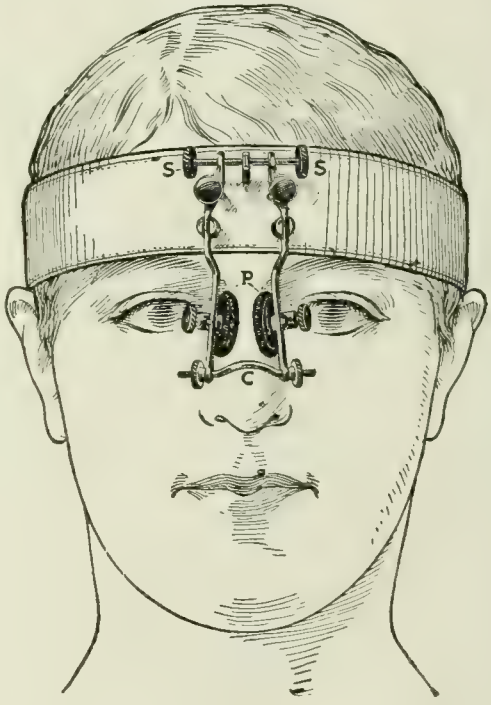


Fig. 2548.—Cobb's Nasal Splint as Modified by Eisendrath. (Keen.)

displacement toward the pharynx; their diagnosis is based upon deformity of the contour of the part of the face affected, and upon crepitation; they are all subject to one important complication, namely sepsis, and they all share in the advantages attaching to the exceptionally abundant blood supply of the face, which makes possible the viability of fragments which, but for this exceptionally rich source of nutrition, would seem doomed to necrosis; the prognosis, therefore, is

far better than the alarming appearance of a patient who has suffered such an accident would lead one to suppose. The treatment of all these lesions is substantially along the same lines, viz., replacement of the fragments as nearly as possible by digital manipulation, or where this cannot be thus accomplished, by means of levers, introduced into the natural cavities of the face, or, if need be, through appropriate incisions, which should be made, as far as possible, through the mucosa of the mouth or of the nose rather than through the integument of the face. In some instances wiring of the fragments may be required. In fractures of the nasal bones, special splints, of which that of Cobb represents the most approved type, may be needed to retain the fragments in position. In view of the tendency of sepsis to appear as the most prominent of the complications, the constant and assiduous use of atomizers and mouth-washes forms an important part of the treatment of these fractures. The repair is generally prompt, and three to four weeks should suffice for a fairly complete cure in cases not complicated by sepsis. Where, on account of sepsis, there follows a certain amount of bone necrosis, healing will not be complete until all fragments of necrotic bone have been thrown off.

Fractures of the Inferior Maxilla.—Fractures of the inferior maxilla are likewise caused by direct violence. The commoner fractures are those of the body and of the alveolar process, and of the fractures of the body a large percentage are multiple. Fractures of the ramus, of the coronoid process and of the condyle also occur; of these the last, particularly, is subject to marked and characteristic displacement, due to the unopposed action of the pterygoid muscles, and is particularly difficult to correct. Uncorrected displacement of the fragments in fractures of the lower

Fig. 2584.—Barton's Bandage Modified by the Addition of a Circular Fronto-occipital Turn.

jaw leads to imperfect alignment of the teeth, and more or less pronounced and troublesome interference with the function of mastication. The diagnosis in fractures of the body of the jaw is rarely difficult, being founded on palpation, inspection and the history of direct violence. By these means abnormal mobility, crepitation and imperfect alignment of the teeth can generally be readily distinguished. The diagnosis of fracture elsewhere in the bone demands careful search, and is at times obscure. The chief complications are a degree of malunion interfering in a most troublesome manner with mastication, and sepsis due to the fracture being, in the majority of cases, compounded into the mouth. The prognosis as to life and as to bony union is on the whole good, but as to the perfect restoration of the line of the teeth, the prognosis must be somewhat guarded.

Fig. 2550.—Four-tailed Sling. (Bryant.)

The treatment must in all cases take into account the peculiar liability of these fractures to septic complication and must include antiseptic measures of the most efficacious possible kind. Fixation of the fragments can in the simpler cases be obtained by simply fastening the jaws firmly together with an appropriate bandage, a Barton's bandage or a four-tailed sling. In many cases it is advisable to wire the bone, and in some the more elaborate protection of an interdental splint will be required to maintain a proper alignment of the teeth.

Fractures of the Sternum.—Fractures of the sternum may be caused by direct or by indirect violence. The fractures by direct violence are generally the result of a crushing force applied to the thorax, and are apt to be accompanied by such extensive damage to the thoracic viscera as to prove promptly fatal. Those by indirect violence, on the other hand, arise from forcible flexion or extension of the spine, both dorsal and cervical, and if they are not accompanied by simultaneous fracture of the vertebræ and by lesions of the spinal cord, offer very fair hope of recovery. The commonest situation of the fracture is at or near the junction of the manubrium with the corpus, and the displacement is very constantly one of the manubrium backward. Reduction is accomplished by forcible extension of the spine over a block or a cushion or over the end of a table, bringing up the arms as in Sylvester's method of artificial respiration. Simple rest in bed may suffice for the after-treatment, or it may be deemed wise to encase the thorax in a plaster jacket.

Fractures of the Ribs.—Fractures of the ribs vary in severity according to the number of ribs involved and according to the extent of the concomitant intrathoracic injury. These fractures may be caused either by direct violence at the site of the fracture or by bending of the ribs through pressure upon the thorax. There is generally but little displacement, owing to the restraining influence of the intercostal muscles. The diagnosis is generally based upon crepitus and upon the eliciting of pain at the site of the fracture when pressure is made upon the affected ribs at points somewhat remote from the fracture itself. The most important complications, aside from the graver injury to the thoracic viscera in extensive crushes, which, indeed, are very generally and promptly fatal, are emphysema, pneumothorax and hemothorax. Emphysema appears in two forms: first, a cutaneous emphysema, which has but rarely any important clinical significance, and secondly, a mediastinal and interlobular emphysema which is a matter of the greatest gravity leading to a

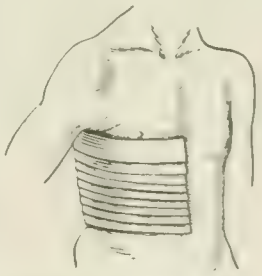


Fig. 2551.—Strapping a Chest for Fracture of the Ribs.

condition of suffocation. The latter form of emphysema is rare. The treatment is by strapping the chest, to restrain costal, and to enforce diaphragmatic breathing, and by the free exhibition of opiates, to slow the respiration, to check cough and to ease pain. Emphysema, if troublesome, may be somewhat relieved by multiple scarifications; pneumothorax may be relieved by frequently repeated aspiration through a fine hypodermic needle. Hemothorax may require thoracotomy, best performed under differential pressure.

Fractures of the Pelvis.—Fractures of the pelvis are divided into two categories, those that do, and those that do not involve rupture of the pelvic ring.

Fig. 2552.—Double Vertical Fracture of Pelvis. (Dennis)

The fractures which involve the integrity of the ring may be single but are more commonly multiple, the ring being broken in two places. More commonly both of these breaks in the ring lie anterior to the interacetabular line, as the pelvic bones are slighter in front, but it is not rare to have one element of these multiple fractures, known as double vertical fractures of Malgaigne, anterior to, and the other posterior to the acetabulum, the posterior line crossing the iliac crest or even the lateral masses of the sacrum; not infrequently for the posterior element in a double vertical fracture is substituted a diastasis of one of the sacroiliac synchondroses. The gravity of these fractures is dependent upon two factors, first the general shock resulting from the very considerable amount of violence by which they are produced, and secondly the injury caused to the intrapelvic viscera, of which lesions those of the bladder and of the urethra easily hold the first place. The diagnosis is greatly facilitated by careful palpation of the true pelvis through the rectum or the vagina, which should be practiced in all suspected pelvic fractures. External palpation is much less apt to reveal the lesion, though appropriate manipulations may reveal pain due to pressing together the broken surfaces.

The treatment of the fracture itself is generally of the simplest, consisting chiefly of rest in bed and a firm girdle about the pelvis. The treatment of possible complications is, however, of the highest importance, and a careful investigation of the urinary organs is demanded in all cases, which should include the passage of the catheter in any case where spontaneous urination is not easy and the urine is not demonstrably free from blood. On evidence of a vesical or of a urethral lesion it is good practice to perform a perineal section at once, without waiting for the appearance of further urinary complications, in all cases where the patient is not evidently moribund from the primary shock of the accident. In many cases of double vertical fracture there will be an indication for the application of an extension apparatus to the thigh.

Single fracture of the anterior part of the pelvis, provided it breaks the continuity of the pelvic ring, is also liable to bring with it vesical and urethral complications, in the absence of which the lesion may be considered to have a distinctly favorable prognosis.

Fracture of the floor of the acetabulum may occur without completely breaking the pelvic ring, and the femoral head may even be driven part way into the pelvic cavity, a lesion known as "central dislocation of the hip"; such a lesion would require an extension apparatus applied to the thigh, or a plaster-of-Paris spica for fixation.

Portions of the acetabular rim may be fractured as an accompaniment of dislocation of the femur. Such a lesion would be recognized by the ready recurrence of the femoral dislocation after reduction. Extension, or plaster-of-Paris fixation or both would be indicated in its treatment.

Isolated fracture of the os pubis, of the ilium, of the ischium, of the sacrum and of the coccyx have been observed. Of the ilium the crest and the anterior superior spine have suffered fracture most frequently, but the lesions have not been grave. Fractures of the sacrum and of the coccyx are prone to involve difficulties with defecation which, however, have rarely proved to be permanent, even where perfect reposition of the fragments has not been obtained.

Fractures of the Clavicle.—Fractures of the clavicle are among the commonest of all fractures and are particularly likely to occur in children. By far the commonest site of the fracture is in the middle third of the bone, where the fracture is generally produced by indirect violence transmitted through the shoulder. When the fracture is transverse there may be but very slight deformity, but in the vastly more frequent oblique fractures the deformity is highly characteristic and is due to the loss of the strut which holds the shoulder away from the thorax. The default of this strut allows the weight of the arm, aided by the action of the humerothoracic muscles, to carry the shoulder downward, forward and inward, and the outer fragment of the broken bone is almost always carried behind and below the inner fragment which it serves to push upward, which upward tilting of the inner fragment is also favored by the only partially opposed action of the sternocleidomastoid muscle. The diagnosis is made from the characteristic attitude of the patient, from his inability, except in cases of transverse fracture, to abduct the arm, from the deformity of the bone, evident both to palpation and to

vision, and from the crepitation which is readily evoked. The complications are few, the most common of them being pressure upon the brachial plexus from exuberant callus, which forms in cases where the reduction and the fixation have been imperfect. The prognosis as to bony union and as to good function of the arm is excellent, but the prognosis as to recovery without a certain measure of shortening is much less favorable.

Fig. 2553.—Fracture of Infantile Clavicle by Infraction. The direct thrust on the shoulder causes the bone to bend by emphasizing its curves and occasions a transverse fracture by infraction; not infrequently a subperiosteal fracture and occasionally a green-stick fracture. (Bull.)

The indications for treatment are to carry the displaced shoulder upward, outward and backward, and to maintain the shoulder in this position until the bone shall have so far knit as to prevent a recurrence of the deformity. The great variety of dressings and of special appliances to this end may serve as an indication of the difficulty of its accomplishment. Most methods of treating fracture of the clavicle depend upon an exaggeration of the correction is one direction to make up for deficient correction in another. The better forms of treatment serve to correct fully at least two out of the three elements of the deformity. The posterior binaxillary figure-of-eight, by exaggerating the backward pull, seeks to keep the shoulder as remote as possible from the sternum, but when applied snugly enough to attain its object it is unbearable to the patient, its lack of upward lift can be remedied in a measure by a mitella beneath the forearm and underneath the elbow. The Velpeau's bandage, which is frequently applied in this lesion, is in every way bad, as its circular turns, by crowding the shoulder toward

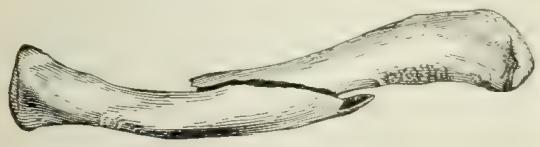


Fig. 2554.—Fracture of Adult Clavicle. The rigid bone does not bend and the direct thrust causes an oblique fracture. In a case observed by Chassaignac the clavicle was split into an anterior and a posterior half. (Stimson.)

Fig. 2555.—Attitude of Patient with Fracture of the Clavicle.

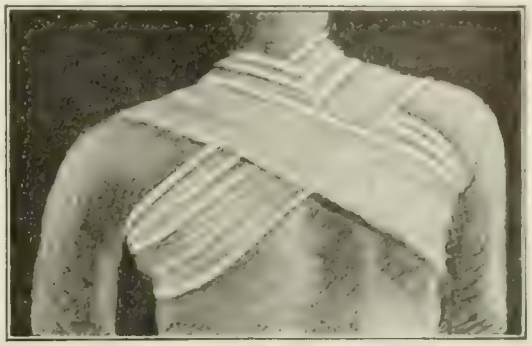


Fig. 2556.—Binaxillary "Figure-of-eight."

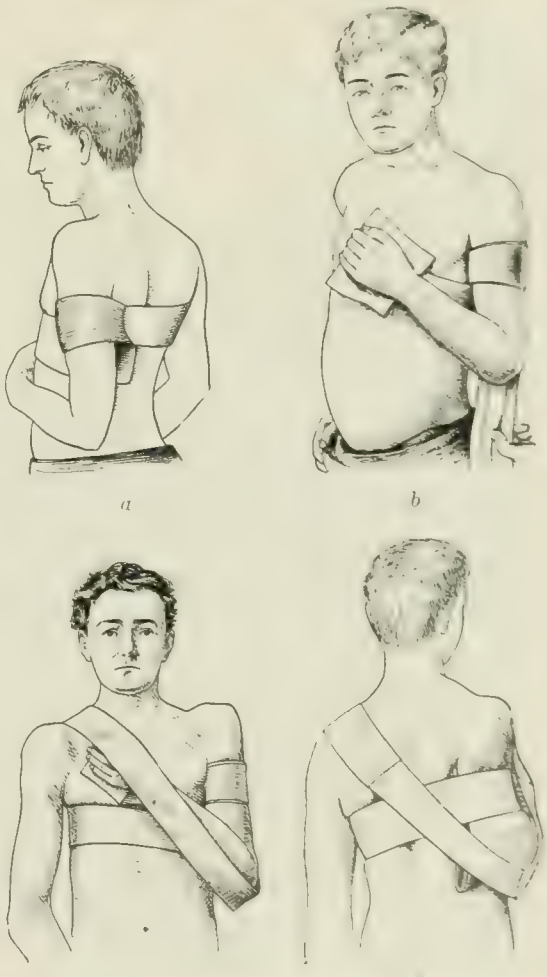


Fig. 2557.—Sayre's Dressing for Fracture of the Clavicle. Note that in (a) the first adhesive strip is applied so as to draw the upper arm distinctly backward. This backward position of the arm is still seen in (b), while in (c) the tightening of the second adhesive strip has forced the hand upward on the thorax till the fingers reach the opposite clavicle.

the sternum, do more harm than its oblique turns, by lifting the arm and the elbow, can offset. The Sayre dressing seeks, by exaggerating the upward lift, and by the backward leverage to compensate for its failure to hold the shoulder away from the sternum; the

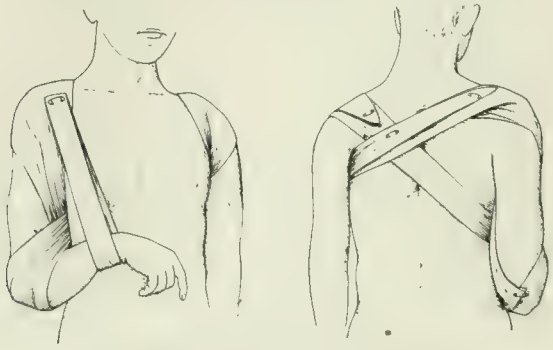


Fig. 2558.—Moore's Dressing. (Stimson.)

alleged prying out of the upper end of the humerus by a fulcrum formed by the more prominent ribs, is quite mythical. Axillary cushions, if large and thick enough to be effective, are dangerous from the pressure which they cause on the inner side of the upper arm. The Moore dressing has no method but that

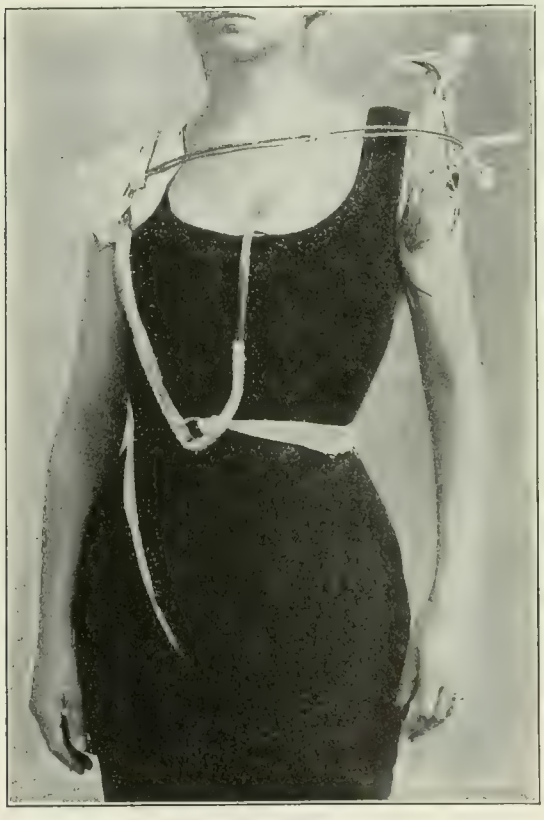


Fig. 2559.—Pivot-yoke. Front view

of an exaggerated lift for maintaining the proper distance between the shoulder and the sternum; it is valuable chiefly as a convenient emergency dressing. A really rational means of securing the desired position of the shoulder must establish a fixed point above, external to and at the same time behind the point of the shoulder, and must connect the shoulder with this fixed point in some convenient and comfortable manner. Loops or bands passing through the axilla must of necessity cause more or less injurious and more or

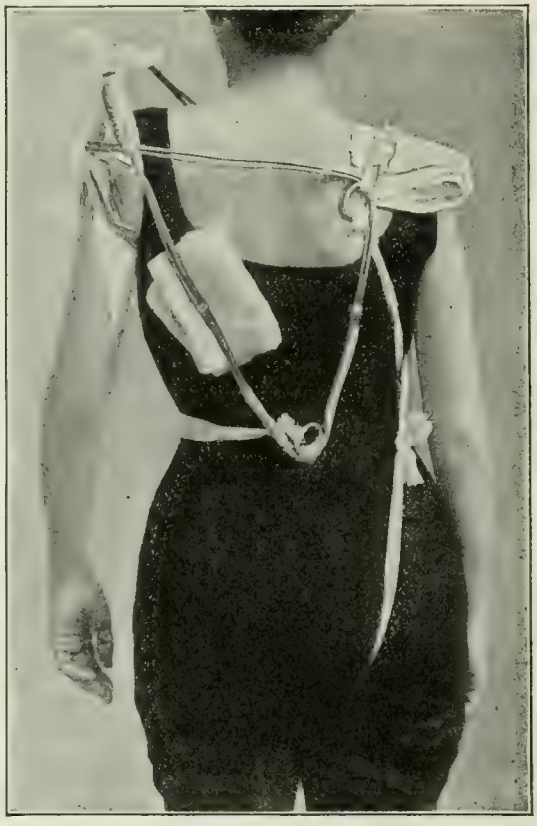


Fig. 2560.—Pivot-yoke. Rear view.

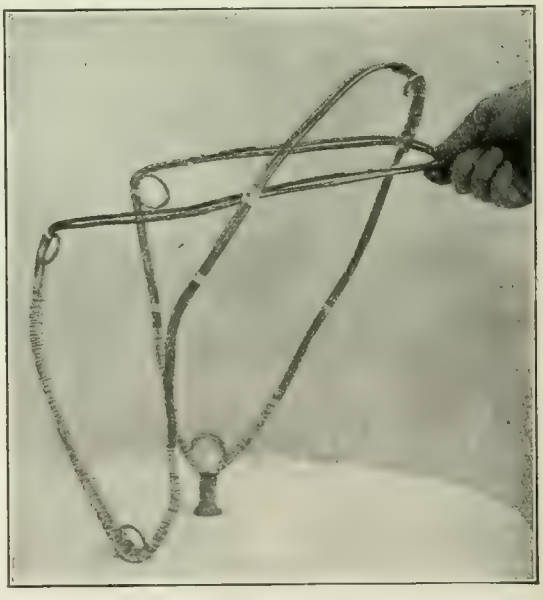


Fig. 2561.—Pivot-yoke Fashioned from Telegraph Wire.

less uncomfortable axillary pressure. It has occurred to the writer to apply to the upper arm adhesive strips, after the analogy of a Buck's extension of the thigh, and to connect these adhesive plaster strips with a fixed point in the desired situation by means of a "pivot-yoke" which is shown in the illustration. Such an apparatus has proved efficacious in practice, and has the unique merit among devices for fractured clavicle of being fairly comfortable to wear.

Fig. 2562.—Adhesive-plaster Dressing for Fracture of External Third of the Clavicle. (Stimson.)

Fractures of the inner third of the clavicle are characterized by an exaggerated upward tilting of the internal fragment. Their treatment may well be along the same lines as that of the commoner fracture of the middle third. Fractures of the outer third of the clavicle, on account of the broad insertions of the coracoclavicular ligaments (the conoid and the trapezoid), are not subject to the same displacements or deformity as fractures of the remainder of the bone. These fractures, which are rare, can generally be treated most advantageously with crossed adhesive strips applied as recommended by Stimson for dislocation of the outer end of the clavicle.

Fractures of the Scapula.—Fractures of the scapula are not common, owing to the elastic bed upon which the greater part of the scapula reposes, and owing to the ease with which it can glide away from any fracturing force. The commonest scapular fractures are those of the body, generally roughly transverse, occasionally stellate; fractures of the spine, of the coracoid process, of the acromion and of the lower angle are occasionally seen, while smashing fractures of the glenoid cavity and less extensive fractures of the lip of this structure are occasional accompaniments of humeral fractures or dislocations.

The crossed adhesive plaster strips alluded to in the preceding section would be appropriate for the treatment of fractures of the acromion; the remaining scapular fractures if they demand any further treatment than support of the arm in a mitella and rest, might well be treated by strapping of the thorax, as recommended for the treatment of fractures of the ribs, with a view to restraining in a certain measure the play of the scapula upon the chest.

Fractures of the Humerus.—*Fractures of the upper end* of the humerus are such as occur from the head of the bone to the point of attachment of the pectoral and the latissimus dorsi muscles. These fractures fall naturally into three classes, those of the anatomical neck, those through the mass formed by the two tuberosities, along a line representing more or less closely the epiphyseal cartilage, pertubercular fractures, and, in the third place, fractures which occur below the tuberosities yet above the lower limits we have ascribed to the upper end of the bone—subtubercular fractures.

Fractures of the anatomical neck of the humerus are very rare though their occurrence has been attested both by operation and by the *x*-ray. They have been most frequently the result of a fall directly upon the shoulder, and are occasionally accompanied by dislocation toward the coracoid process. The separated head has been observed in some instances to have undergone wide displacement, amounting, in several cases, to a complete revolution, so that its fractured surface looked toward and its articular surface away from the glenoid cavity. In cases of wide displacement of the head operative interference is indicated, and resection of the head of the bone is generally the most feasible method of treatment. Where the displacement is less considerable, continuous traction on the humerus is the most satisfactory method of treatment.

Pertubercular fracture of the upper end of the humerus is the commoner type of fractures in this vicinity. The cause may be either direct violence applied to the shoulder or violence transmitted through the humeral shaft from a fall on the hand. The line of fracture is very constantly oblique from above downward and from without inward. The inner termination of the fracture line is generally very close to the junction of the lower border of the head with the shaft of the bone; the outer end of the line of fracture may vary considerably in its distance from the upper border of the head, the pertubercular fractures thus merging insensibly into those more strictly of the anatomical neck above, and into the class of subtubercular fractures below. These fractures through the tuberosities have most frequently and characteristically a displacement forward and inward, which is generally revealed with some clearness by a careful scrutiny of the axis of the shaft of the bone as a whole. When the usual displacement is present, a view of the arm from in front will show the axis deflected toward the coracoid process, much as in a subcoracoid dislocation, from which it may however be distinguished by two points: first, the shoulder will not have lost to any great extent its normal rotundity, owing to the fact that the head of the humerus still lies in the glenoid cavity, where it may be palpated beneath the acromion process; second, the elbow, even if it does not lie in actual contact with the thorax, can be made to approach the thorax without the elastic resistance which is characteristic of subcoracoid dislocation.

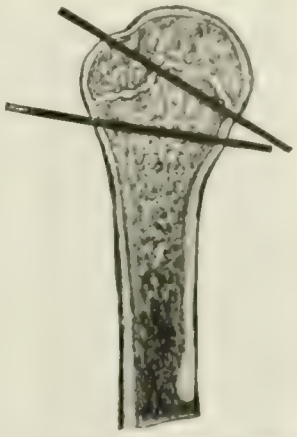


Fig. 2563. Limits and Direction of Pertubercular Fracture of the Humerus. Fractures above the upper limit are properly fractures of the anatomical neck; those below the lower limit are subtubercular fractures. The figure shows the epiphyseal cartilage.

Fig. 2564. — Pertubercular Fracture Viewed from the Front, showing Characteristic Displacement inward. Note dimpling of the skin over end of lower fragment. (Kocher.)

A further highly characteristic diagnostic point is quite frequently, though not constantly, to be observed, namely, a dimpling of the skin on the front of the upper arm caused by the engagement of a spicule of bone on the upper end of the lower fragment in the deeper layers of the corium. When the arm is viewed

from the side there will be observed, when the usual displacement is present, a forward deflection of the humeral axis, so that it is no longer pointed directly toward the acromion, but its line, if projected, would pass somewhat in front of this process. In the less common displacement backward and outward, the lines of axial deflection will be correspondingly altered, and they are, withal, less clearly to be made out. In young patients a genuine epiphyseolysis will generally take the place of a pertubercular fracture of the bone. Both in true fractures and in epiphyseolysis the inward and forward displacement is at times so extreme that the shaft is carried completely past the upper fragment and overriding results, which may offer the greatest difficulties to reduction, necessitating, in the majority of cases, a resort to open operation. Except where very perfect reduction can be obtained, the best treatment of pertubercular fracture of the humerus is by continued traction, and not infrequently it will be necessary to make this traction in two directions, *i.e.* in the axis of the arm, which should at least be moderately abducted from the body, and likewise, through the means of a separate band and weight, in a direction calculated to overcome the tendency to inward displacement.

Fig. 2565. — Pertubercular Fracture Viewed from the Side, showing Characteristic Displacement forward. (Kocher.)

Fractures where the outer end of the fracture line is situated more than an inch below the top of the humeral tuberosities are known as subtubercular fractures. The displacement in subtubercular fractures is best described as being a displacement of the upper fragment, which, inasmuch as it remains under the control of the rotators and abductors that are inserted into the tuberosities, is, when released from its connection with the shaft of the bone, carried by these muscles into a position of abduction and external rotation, a position to which it is necessary to accommodate the humeral shaft in doing up the fracture. The treatment is similar to that of fractures of the humeral shaft rather than to that of the other fractures of the upper end of that bone, and is discussed below.

Fig. 2566.—Abduction and External Rotation of Upper Fragment in Subtubercular Fracture. Union in this position will give permanent impairment of function. (Dennis.)

Besides the three main types of fracture of the upper end of the humerus already mentioned we have also various forms of comminution of the bone which on analysis can generally be resolved into combinations of any two of the three principal types of fracture, and are known as V-fractures or as Y-fractures according to the direction of the fracture lines, which, with a fair degree of constancy, are more or less widely separated on the external side of the bone, to approach or to meet one another on the inner side of the bone near the lower border of the head. These fractures are almost always the result of direct violence to the shoulder of a degree considerably greater than would suffice to occasion a simple pertubercular fracture. Their treatment should be along the general lines suggested for the simpler fractures, but the reposition and retention of the fragments is much more difficult and calls more often than do the simple fractures for mechanical fixation by open operation. Even under the most favorable conditions the prognosis as to complete recovery of the functions of abduction and rotation can hardly be regarded as more than fair.

Isolated fracture of one or of both tuberosities is sometimes seen as the result of direct violence to the shoulder, or even as the result of muscular action. The difficulty of retaining the small fragments in

Fig. 2567.—Y-fracture of Upper End of Humerus; almost always a compression fracture by severe direct violence. (Internat. Textbook of Surgery.)

position by any means short of fixation by open operation is very great, though something can be done by accommodating the position of the humeral shaft to the position of extreme abduction and external rotation which the separated fragments are forced to assume under the unopposed action of the inserted muscles. Failing proper reposition these important functions will be largely abolished. See Fig. 2566.

The shaft of the humerus is subject to a variety of fractures, among which spiral fractures are conspicuous both by their frequency and by the difficulty of reduction and retention. When these fractures occur below the middle of the shaft, a serious complication may develop if exact reposition cannot be maintained, namely, the inclusion of the musculospiral nerve in the callus, a mishap which will call for freeing the nerve from the callus by operative means, to restore the function of the extensor muscles of the forearm. Some obstinate fractures of the shaft of the humerus will demand continuous traction during the first part of the treatment. In a majority of

the cases, however, the treatment should consist in binding the arm upon an axillary cushion which will support it firmly and comfortably against the side of the body. The upper arm should be first surrounded with several narrow coaptation splints, fastened with adhesive strips. The axillary pad should be made of folded layers of cotton or of sheet-

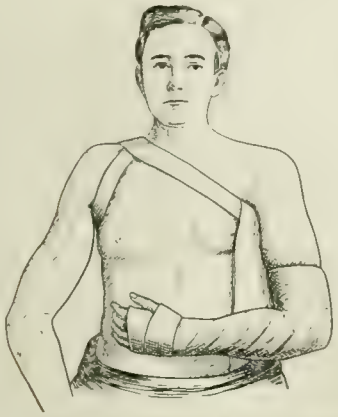


Fig. 2568.—Strohmeyer's Axillary Cushion.

wadding covered with pasteboard, and this again covered with a single layer of cotton or of sheet-wadding, the whole finally either wound with bandages or encased in cotton cloth properly stitched. The pad should be wedge-shaped, should be long enough to reach from the apex of the axilla to just below the border of the ulna when the elbow is flexed; it should be about six inches wide, and the upper end should be about one inch, while the lower end should be about three inches, in thickness. To each corner of the thin end should be fastened straps or tapes long enough to pass across the root of the opposite side of the neck and cross under the opposite axilla. The object of the pad is to afford a firm and comfortable bed against

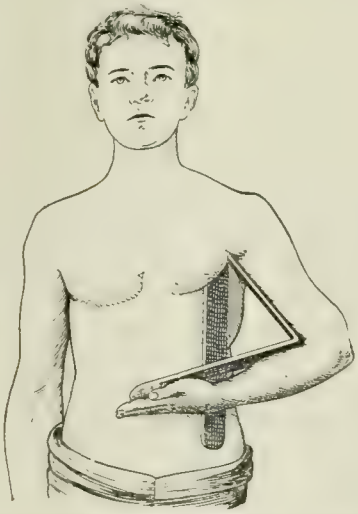


Fig. 2569 —The Frame of v. Hacker's Splint for Fracture of the Shaft of the Humerus. This frame requires copious padding.

which the whole length of the upper arm can rest. When the arm supported by its coaptation splints has been laid upon this bed, it is to be bound firmly to the body by a broad swathe encircling the arm and the thorax. The elbow should remain unsupported, but the wrist should be supported by a sling.

Another simple but ingenious apparatus which can be readily extemporized is the splint used in the clinic of v. Hacker, of Halle. This is illustrated in Fig. 2564.

Comminuted fractures of the shaft of the humerus demand in most cases open operation, and treatment by continuous extension. Only after a week or two is it wise to apply the treatment recommended above for simple fractures. Extension can be conveniently applied in ambulant cases by weights fastened to an internal angular splint which is to be made fast to the forearm but not to the upper arm, lest through fixation of the elbow any motion applied to the forearm, which might well expend itself harmlessly in motion at the elbow-joint, be transmitted past the joint to take effect at the site of the fracture.

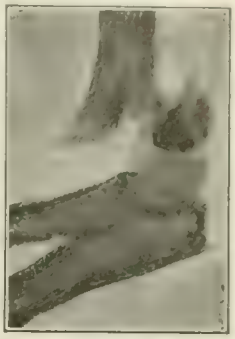


Fig. 2570.—Extension Fracture at Elbow. (Sketch from *x*-ray by Cotton.)

Lower End of the Humerus.—The commonest fractures at the lower end of the humerus are supracondylar fractures by hyperextension, fractures of the external condyle and fractures of the internal epicondyle. The other fractures, which are much more rare, are fractures of the internal condyle, fractures of the articular process, often in the guise of an epiphyseolysis, T-fractures and Y-fractures, in which the condyles are not only separated from the humeral shaft but are likewise split apart, supracondylar fractures by flexion, fractures of the capitellum, and finally, as a great rarity, fracture of the external epicondyle.

The elbow, in common with nearly all the ginglymoid joints of the body, is subject to two characteristic types of fracture, extension fractures and flexion fractures. These fractures are caused by leverage exerted on the bone through the medium of the joint ligaments. In extension fractures at the elbow-joint the force is commonly applied through a fall upon the hand, whereby the anterior portion of the capsular ligament is made taut. Should the ligament give way more easily than the bone, the result will be a backward dislocation of the bones of the forearm, but should the ligament not yield, a fracture of the humerus will be the consequence, which fracture will start at the line of the attachment of the capsular ligament anteriorly and will proceed upward and backward, allowing the bones of the forearm to become displaced substantially as in a backward dislocation, yet still maintaining their normal relation to the lower fragment of the humerus, which, owing to the intact lateral ligaments of the joint, accompanies the bones of the forearm in the backward displacement. The result is that the sharp chisel end of the upper fragment becomes prominent at the bend of the elbow, where it is capable of doing great damage

Fig. 2571.—Backward Dislocation of Elbow. (Sketch from *x*-ray by Cotton.)

to the cubital vessels and nerves. While an extension fracture is generally caused by an actual hyperextension of the joint, a flexion fracture is the result of a virtual, rather than an actual, hyperflexion. The force which actually produces a flexion fracture is generally a fall upon the partly or fully flexed elbow, but the mechanics of the fracture is substantially the reverse of what we have described as that of an extension fracture. In a flexion fracture the posterior portion of the capsular ligament is made taut, and the fracture starts at the line of attachment of this portion of the ligament to the humerus, and extends obliquely upward and forward. Had the capsule yielded before the bone, the result would have been a forward dislocation of the bones of the forearm. In case of bone fracture the lower fragment is carried forward, still attached to the radius and the ulna by the intact lateral ligaments of the joint, and the chisel end of the upper fragment juts out backward, and not infrequently transfixes the triceps tendon and may even protrude through the skin. The damage that will be done by the sharp edge of the upper fragment is evidently far less, barring the possibility of infection of a compound fracture, in flexion fractures than in extension fractures. Extension fractures are much more common at the elbow than are flexion fractures.

Supracondylar Fractures by Extension.—Supracondylar fractures of the humerus by extension have many resemblances to a backward dislocation of the elbow; the most obvious points of differentiation are the

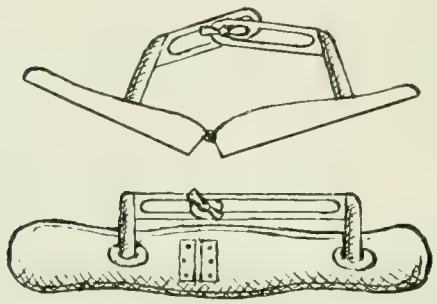


Fig. 2572.—Anterior Hinged Splint for Fracture about the Elbow Joint.

different shape and make-up of the anterior and of the posterior protrusions, the occurrence of crepitation in fracture, and the reduction of the deformity in fracture by simple forcible traction in the axis of the arm. Extension fractures of the humerus have in common with backward dislocation of the elbow abnormal mobility both in the sense of hyperextensibility and a preternatural adduction and abduction, and furthermore, in both lesions flexion of the elbow is impeded.

In the treatment of extension fractures at the elbow rest and support are of far greater importance than is the particular degree of flexion or of extension which is to be imparted to the elbow-joint. After rest and support have been provided by proper splinting in any convenient position, the next most important matter is the frequent changing of the degree of flexion of the elbow to secure the widest possible range of motion in the joint after healing of the fracture. It is good practice to change the degree of flexion every two days, splinting the arm securely in the new position. For the first two or three dressings the arm should be brought nearer and nearer to complete flexion, and for the next two or three dressings, nearer and nearer to complete extension. An adjustable anterior hinged angular splint is convenient for all the dressings but those of nearly complete flexion. These positions of nearly complete flexion can best be obtained by means of a strip of adhesive plaster running along the posterior aspect of the forearm, the wrist and the hand, and from thence across the trapezius of the injured side and down the back between the scapulæ, as shown in the illustration.

One particular form of malunion is prone to follow supracondylar fractures of the humerus, namely, a gunstock deformity, or cubitus varus. This deformity is not caused, as was at one time supposed, by the slipping down of the external condyle along the shaft, in isolated fracture of that process, but is the result of a tilting of the whole lower fragment in supracondylar fracture. It is best guarded against by a splint applied firmly on the inner side of the upper arm in such a manner as to exert some pressure on the internal condyle, its action being emphasized by a similar splint applied to the outer side of the upper arm, and so padded as to make pressure above the external epicondyle. The lesion is unsightly but does not interfere seriously with the function of the arm. It can readily be corrected by a cuneiform osteotomy.

Fig. 2573.—Adhesive-plaster Dressing for Maintaining Full Flexion of the Elbow.

Fracture of the External Condyle.—Fracture of the external condyle is generally the result of a fall upon the hand in which the force is transmitted along the shaft of the radius directly to the capitellum. The delay in the union of the center of ossification for the capitellum with the diaphysis predisposes children and adolescents to this fracture, which is, however, by no means rare in adults. Certain bizarre and unusual forms of displacement occur in this fracture, due to the persistent attachment of the external lateral ligament of the elbow-joint to the fragment. The difficulties of accurate replacement and retention may necessitate the excision of the condyle, which operation does not seriously interfere with the function of the elbow. The diagnosis of fracture of the external condyle is based on the possibility of marked adduction of the forearm, and it is to be differentiated from a complete supracondylar fracture by the fact that there is not any similar degree of abduction possible. The fracture can be differentiated from a sprain by the pain caused by upward pressure in the line of the shaft of the radius, and by crepitation and mobility of the fragment. The treatment, except in cases of extraordinary displacement which may require excision, is similar to that of supracondylar fracture.

Fig. 2574.—Gunstock Deformity after Supracondylar Fracture.

Other Fractures of the Lower End of the Humerus.—Fracture of the internal epicondyle is caused by any force which forcibly abducts the forearm, and occasionally by a blow upon the epicondyle from behind. (See Fig. 2539.) The fragment broken off is often very small but it carries the insertion of the internal lateral ligament of the elbow-joint; as a consequence the extended forearm is capable of a wide degree of abduction, as opposed to the adduction producible in fracture of the external condyle. A considerable amount of hyperextension is also possible, owing to the more or less extensive laceration of the anterior portion of the capsular ligament, and crepitation and independent mobility of the fragment can ordinarily be demonstrated without difficulty. The displacement of the fragment is almost constantly downward and forward, but occasionally it may be dragged into the interior of the joint capsule, where it may present a considerable obstacle to flexion. This, however, is rare. This fracture, not being to any great degree an articular fracture, does not threaten to involve the elbow in ankylosis; the more elaborate precautions against this mishap are therefore not needed, as in most fractures about the elbow-joint. The best method of treatment is in a position of full flexion, maintained by the simple adhesive strip described above as applicable to supracondylar fractures. (See Fig. 2573.) After ten or twelve days the arm may be released from this rather irksome confinement and be supported across the thorax in a simple mitella.

Fig. 2575.—Fracture of the External Condyle, showing rotation of the fragment. (Kocher.)

Fractures of the articular process (fracturæ diacondylicæ) are generally caused by a fall on the flexed elbow. They occur most commonly in the young in the shape of an epiphyseolysis. Their

Fig. 2576.—Epiphyseolysis of Lower End of Humerus. Note shape of Epiphysis. (Drawing from *x*-ray by Scudder.)

symptoms are largely those of a loose body in the elbow-joint, giving an obstacle to flexion and extension which can generally be overcome by the exercise of slight force. Their treatment should be along the lines laid down for treatment of supracondylar fractures from which they may be distinguished by the limited extent to which the signs common to both lesions can be demonstrated. A further distinction lies in the absence of any independent mobility of the epicondyles.

T-fractures and Y-fractures of the lower end of the humerus are caused by an extreme degree of violence applied to the elbow itself, as from a fall from a considerable height. The fracture line at the separation of the condyles from the shaft is consequently generally oblique from behind forward and from below upward, in the general sense of a flexion fracture, as opposed to that of an extension fracture; the chief damage to the surrounding soft parts is therefore generally at the back rather than at the front of the elbow. The intercondylar portion of the fracture, representing the stem of the T or of the Y, is caused by the pressure of the diaphysis upon the lower fragment splitting it into two lateral portions. These fractures are not infrequently compound. Their treatment should be along the lines already laid down for the treatment of supracondylar fractures, but the changes of position should be more frequent and should be less in degree. Even under the best of care these severe fractures, especially if compound, give as a rule but imperfect results as regards restoration of the function of the joint.

Fig. 2577.—T-fracture of Lower End of Humerus. Note that the obliquity of the upper fragment corresponds to a flexion fracture and that the anterior cubital structures are spared while the fracture tends to be compounded posteriorly. (Kocher.)

Supracondylar fractures by flexion (see Fig. 2543 demand much the same treatment as extension fractures, only it is advisable in changing the position of the arm to make the first series of changes in the direction of greater and greater extension, and to begin the series of changes in the direction of flexion only after the fragments shall have acquired at least a certain slight degree of fixation through the advance of the healing process.

In a certain number of cases there has been noted the forcing off of the articular surface of the capitellum under the influence of heavy lifting with flexion of the forearm, through the extreme pressure of the head of the radius against the humerus. The fracture is not always painful, and reveals itself chiefly through the displacement of the fragment into the joint as a loose body where it causes a characteristic interference with flexion and extension. The treatment is by excision of the fragment which is without serious detriment to the elbow.

Fig. 2578.—Fracture of Capitellum. The fragment forms a loose body in the joint. (Kocher.)

A word of caution is in order with regard to extension fractures and to comminuted fractures about the elbow-joint, concerning more especially the laceration of the cubital vessels. Where the appearance of an unusual degree of swelling makes probable a considerable vascular laceration, and particularly where the radial pulse is not to be felt with satisfactory distinctness, the surgeon should exercise the greatest caution, in applying dressings or splints, to avoid interfering by any avoidable pressure with the already impaired circulation of the forearm, for fear of inducing an ischemic contracture, which is essentially a progressive degenerative myositis leading to the substitution of non-contractile fibrous connective tissue for the contractile muscle tissue. This condition, known also as a Volkmann's contracture, leads to more or less complete abolition of the functions

of the hand, and may be almost irremediable by art. A deficient supply of blood to the muscles is the essential etiological factor in the lesion, and to this tight bandaging may contribute in an important degree, especially in cases where the primary extensive laceration of the vessels has afforded a strong predisposition. This is a frequent occasion for malpractice suits.

Fig. 2579.—Position of Hand and Fingers in Volkmann's contracture. Site of pressure cicatrix is indicated on forearm.

Fractures of the Forearm.—Fractures of the bones of the forearm appear both as isolated fractures of either bone and as simultaneous fractures of the radius and the ulna. Of fractures of the upper end of the ulna, that of the olecranon process is the most common, though a few cases are on record of fracture of the coronoid process as an accompaniment of a backward dislocation, to be recognized by the facility with which the dislocation recurs after reduction. Fracture of the olecranon is not now believed, as was formerly taught, to be caused in the majority of cases by direct violence to the elbow, but its causation is rather one of leverage across the trochlea of the humerus, which affords a fixed point against which the pull of the triceps above, and a blow upon the shaft of the ulna below, act to break the bone across through the sigmoid notch. The constant tendency to displacement of the fragment is upward, under the traction of the triceps, but, owing to the lateral expansions of the aponeurotic tendon of the triceps, this tendency to diastasis of the fragments does not, in most cases, assert itself very extensively until some time after the fracture; a careful examination is therefore necessary in many cases to determine the existence of this fracture in recent cases. The best treatment is by prompt wiring, which is without dangers save those which may be successfully met by a strict attention to asepsis. In default of operation the arm should be put up in as near an approach to complete extension as the patient can bear with any degree of comfort. The greatest care should be used in flexing the arm little by little for fear of a refracture, or of increasing the diastasis between fragments which are somewhat precariously held together by a ligamentous bond of union. The degree of disability in cases of fibrous union is fairly commensurate with the length of the intervening ligamentary bond. Secondary operation on neglected cases, owing to the permanent contracture of the triceps, gives only indifferent results.

Fig. 2580.—Fracture of Head of Radius. (Dennis.)

The fractures of the *upper end of the radius* include those of the head and those of the neck; fractures below the orbicular ligament are extremely rare, owing to the full protection afforded to the bone by the surrounding muscles. Fractures of the head are seen as separations of a chip from the contour of the circular head and as stellate fractures; in either case the fracture of the head may extend a greater or less distance down the neck. Fractures of the neck may or may not be accompanied with a fracture of the head of the bone. These fractures, owing to the deformation of the head and of the neck, may interfere very seriously with the play of the upper end of the radius in the confined space within which its functions are executed between the orbicular ligament below and the capitellum of the humerus above, and may lead, in consequence, to very grave interference with pronation and supination. These fractures are difficult of positive diagnosis without the use of the *x*-ray, but they

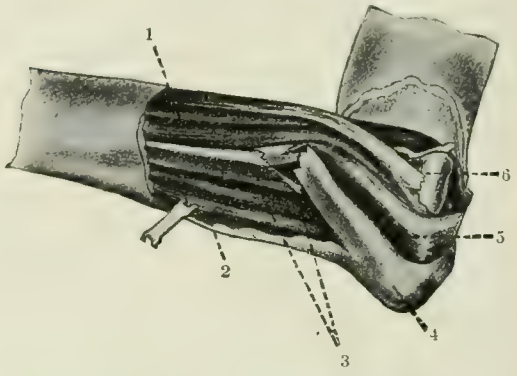


Fig. 2581.—Smashing Fracture of the Upper Third of the Shaft of the Ulna, with forward dislocation of the radius, a frequent complication. (Helferich.)

may be suspected when in an injury to the elbow, without the evidence of fracture of the humerus, there is pain on pressure in the axis of the radius and likewise local tenderness over the radial head, when these signs are accompanied with interference with the function of rotation of the forearm. The smallness and the inaccessibility of the parts makes reposition difficult or impossible, and these fractures are generally best treated by excision of the head of the radius. This may be practised without great detriment to the joint, provided the upper end of the shaft is not allowed to escape from the grasp of the orbicular ligament.

Isolated fractures of the *shaft of the ulna* are seen in two well recognized varieties. The first of these is a smashing fracture of the upper third through direct

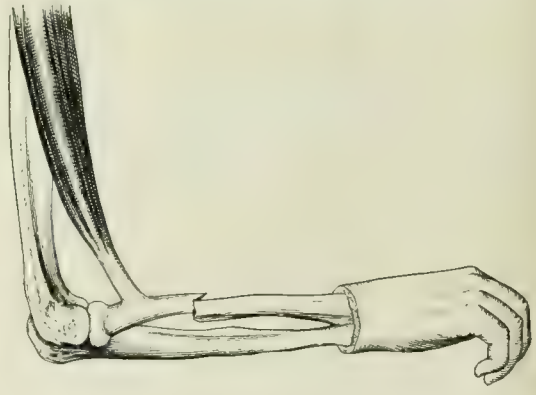


Fig. 2582.—Action of Biceps in Supinating the Upper Fragment in Fracture of the Shaft of the Radius. This action must be met by supinating and flexing the forearm. (Helferich.)

violence from a fall or a blow. These fractures are very apt to be compound and are apt likewise to be accompanied by a forward dislocation of the radius, for which accompanying lesion careful search should be made in every case. The second variety of fracture of the ulnar shaft is perhaps sufficiently described by the name "parrying fractures" which has been applied to them. The superficial situation of the whole of the

ulnar shaft makes these fractures readily accessible to operative reduction and fixation, but where but one bone of the forearm is broken the opposite bone will often afford sufficient support to render the displacement so inconsiderable as to make any operative interference unnecessary, in which case simple splinting, with due regard to the prevention of any encroachment on the interosseous space, will yield satisfactory results.

Fractures of the *shaft of the radius* are rare in the upper portion, which is covered with a thick layer of muscles, but become more frequent nearer the wrist. The higher in the shaft the fracture occurs, the more danger is there of loss of the function of supination if proper attention is not paid to this point in the treatment. The trouble is due to the fact that the biceps acts upon the upper fragment to hold it in a position of complete supination. If now the shaft, with the hand in a position of full pronation, unites with the fully supinated upper fragment, the result will be a complete loss of rotation in both directions. As a matter of fact it is so rarely convenient to put up the arm with the hand in full pronation that this complete abolition of rotary function from this cause is not met, but just in so far as the degree of rotation of the lower fragment fails to correspond to that of the upper fragment will the function of rotation, after union, be permanently curtailed. As the supinating action of the biceps cannot well be con- trolled, it is wise to put up fractures of the radial shaft high up with full supination of the hand. Both relaxation of the biceps and comfortable supination of the hand can best be obtained by the adhesive plaster dressing suggested in discussing the treatment of supracondylar fracture of the humerus. (See Fig. 2573.)

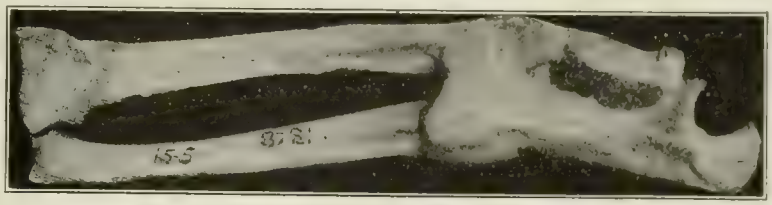


Fig. 2583.—Synostosis of the Bones of the Forearm. (Internat. Texth. of Surgery.)

Fracture of Both Bones.—In simultaneous fractures of both bones of the forearm strict attention must be paid to maintaining the integrity of the interosseous space, lest, should the shaft of the radius approach too nearly to that of the ulna, there may be, in extreme instances, fusion of the callus thrown out by each of the bones (synostosis), and in less extreme instances, such an interference with the play of the bones upon each other as to curtail very seriously the function of rotation of the forearm. Especially is this true when there is comminution of one or of both fractures. Where a satisfactory position of both bones can be secured, the most convenient treatment is with anteroposterior splints which must be slightly broader than the forearm to avoid any lateral pressure on the radius and the ulna calculated to force these bones together; as high a degree of supination as is comfortable to the patient is likewise desirable, but not in all cases indispensable. In cases where satisfactory position is difficult to secure, and in comminuted fractures of one or of both bones, it is well to put up the arm, for some time at least, in torsional suspension. Such an apparatus should be applied in the following manner: It is necessary, in view of the scant area available for the application of adhesive straps, to utilize to the utmost all the available traction surface, and this can best be done by applying eight narrow strips of adhesive plaster, each running from near the site of the fracture, one over the palmar and one over the dorsal surface of each finger, to meet, with their adhesive surfaces opposed, just beyond the finger tips, and be joined there in a single rope. Each finger should be separately and carefully bandaged. A broad strip of adhesive plaster should now be applied on either surface of the wrist and hand, reaching from near the seat of the fracture to the region of the web of the fingers, and the hand and wrist should be covered by a bandage, having due regard to the danger of approximating the radius and the ulna by continuing the bandage too high up the forearm. As the weights to be used must be quite heavy to be effective, it is well to divide the tension of the apparatus between the adhesive plaster dressing just described and a noose made from a worsted skein, or a leather wristlet, at the wrist; the two parts of the traction apparatus should then be connected by a cord passing over a pulley, to which pulley one end of the rope which is to afford the extension is to be made fast; the rope is then to be passed through the suspending pulley and the other end of it is to be tied to the weight. Vertical suspension is to be recommended as obviating any tendency to sagging and consequent angular displacement. In order to

Fig. 2584.—Application of Extension Apparatus to the Forearm

maintain supination it is well, on the left arm, to make use of a rather heavy suspension rope (three-fourth inch), which should be strongly twisted, and the weight prevented from revolving by proper guides. On the right arm such twisting of the rope would lead to pronation, while reversing the twist would simply destroy the rope; for the right arm then, it is necessary to improvise a rope, to be made up preferably of three strands of braided window cord; these can be twisted in the reverse direction from an ordinary cable laid rope, and proper guards to the weight will prevent the twist from loosening. When the suspension rope is twisted to supinate the forearm it is necessary to introduce between the palmar surface of the wrist, hand and fingers and the worsted skein a thickly folded bath-towel or other large pad, to prevent crushing the finger tips. Such a pad should extend indeed an inch or two beyond the tips of the fingers.

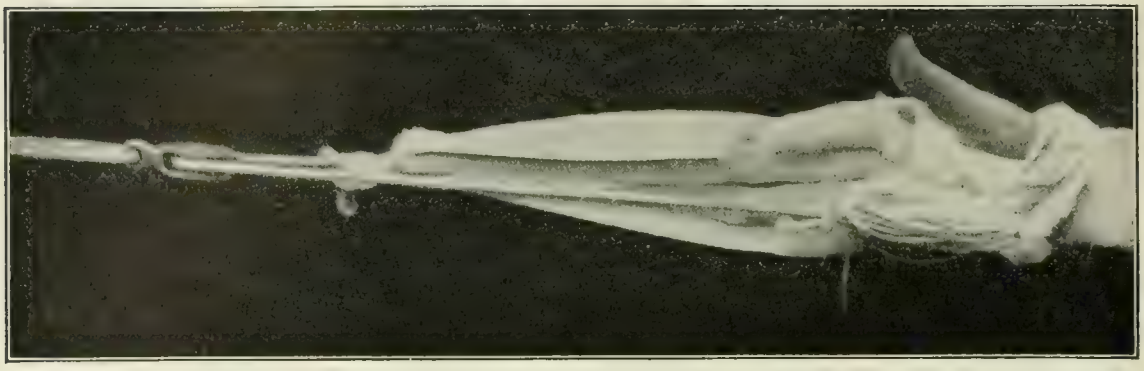


Fig. 2585.—Dividing Traction between Adhesive Strips and Wrist Noose.

Fractures of the *lower end of the ulna* are virtually fractures of the shaft of that bone, with the exception of fracture of the styloid process. This latter fracture is as a rule a relatively unimportant accompaniment of a Colles' fracture of the radius; when, as occasionally happens, it occurs alone, an anterior "pistol-grip" splint is an excellent form of treatment.

Fractures of the *lower end of the radius* are best divided into those that are and those that are not of the type known as a Colles' fracture, and known in European text-book as Dupuytren's fracture of the wrist.

Colles' Fractures.—Colles' fracture in its typical form is properly an extension fracture of the wrist, varying however, somewhat from the more clear-cut extension fractures of the lower end of the humerus, on account of the leverage being transmitted through the flexible chain of the bones of the carpus and the hand, rather than through the more rigid lever of the forearm. A flexion fracture known as a "reversed Colles'" has also been observed. As explained in discussing supracondylar fractures of the humerus, an extension fracture is started by the tug of the anterior portion of the capsular ligament on its insertion into the bone, and from this point the fracture extends obliquely upward and backward. In a flexion fracture, on the other hand, the fracture is started by the tug of the posterior portion of the capsular ligament, and runs from that point obliquely upward and forward. The same phenomena are observed in the fractures by extension and by flexion in the lower end of the radius, though for the reason given they are somewhat less true to type in the radius than in the humerus. In Colles' fracture of the wrist the displacement is generally very promptly limited by a firm impaction of the fragments, but this displacement nevertheless may be analyzed into two elements which it is very important to have distinctly in mind when attempting reduction. The first element of the displacement is a displacement by sliding, in which the lower fragment is carried toward the elbow, but likewise, in a majority of the cases, somewhat outward. The more important of

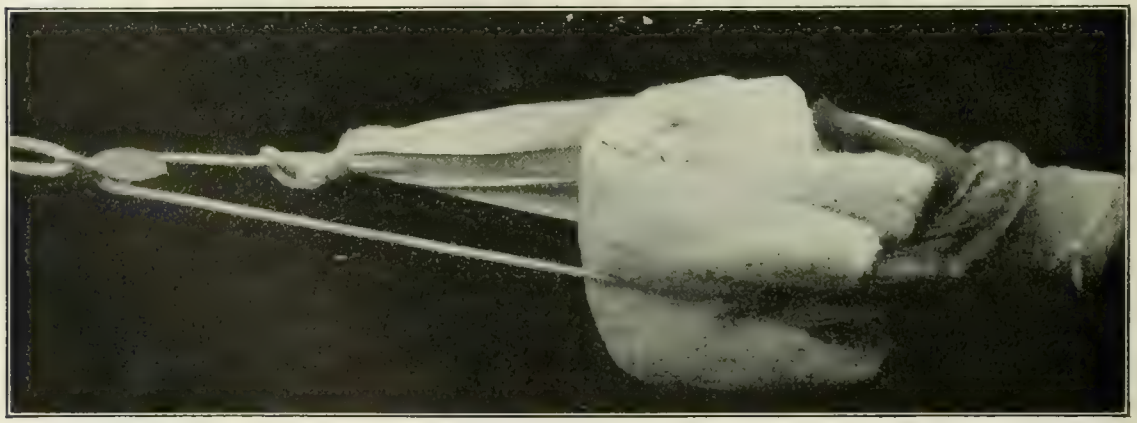


Fig. 2586.—Interposition of Cushion between the Adhesive Strips and the Noose to Prevent Pinching of the Finger-tips in Torsional Suspension.

the two elements of the displacement is, however, a displacement by tilting, in which the articular surface of the bone is deflected, in the commoner extension fractures, backward, and likewise, in the majority of the cases somewhat outward, and in the flexion fractures (reversed Colles' fractures) the articular surface is deflected forward, and at the same time somewhat outward. In the described positions of combined longitudinal and angular displacement the fragments are generally firmly fixed by impaction of the fragments. The resulting deformity is highly characteristic and is almost pathognomonic of Colles' fracture. To it was given by Velpeau the name of "silver fork deformity." Were the flexor tendons of the hand and fingers not active, the position imparted to the hand by the tilting of the lower fragment on the shaft of the radius would exactly resemble a dorsal flexion, but with the transverse axis of flexion a little nearer the elbow; owing, however, to the continued action of the flexors, the metacarpus and the fingers are acted upon in a way to bring the parts beyond the radiocarpal joint into an approximation to their normal relation to the axis of the forearm. The result is a compound curve, much on the lines of the ordinary table fork. This analysis of the deformity will serve to show that it is due more to the displacement of the lower fragment by tilting, than it is to its displacement by sliding, and will, at the same time, make clear why an almost identical deformity can be produced where the lines of fracture may vary very considerably.

A second deformity of the wrist, almost as constant and as characteristic of Colles' fracture as the first, is outward deflection of the hand toward the radial (the thumb) side. This differs from the "silver fork deformity" in being generally a pure deflection, without any correction to bring the axis of the middle finger back into parallelism with the axis of the forearm. A tendency toward the compensation of the deflection by the action of the ulnar muscles can usually be seen in the abduction of the little finger.

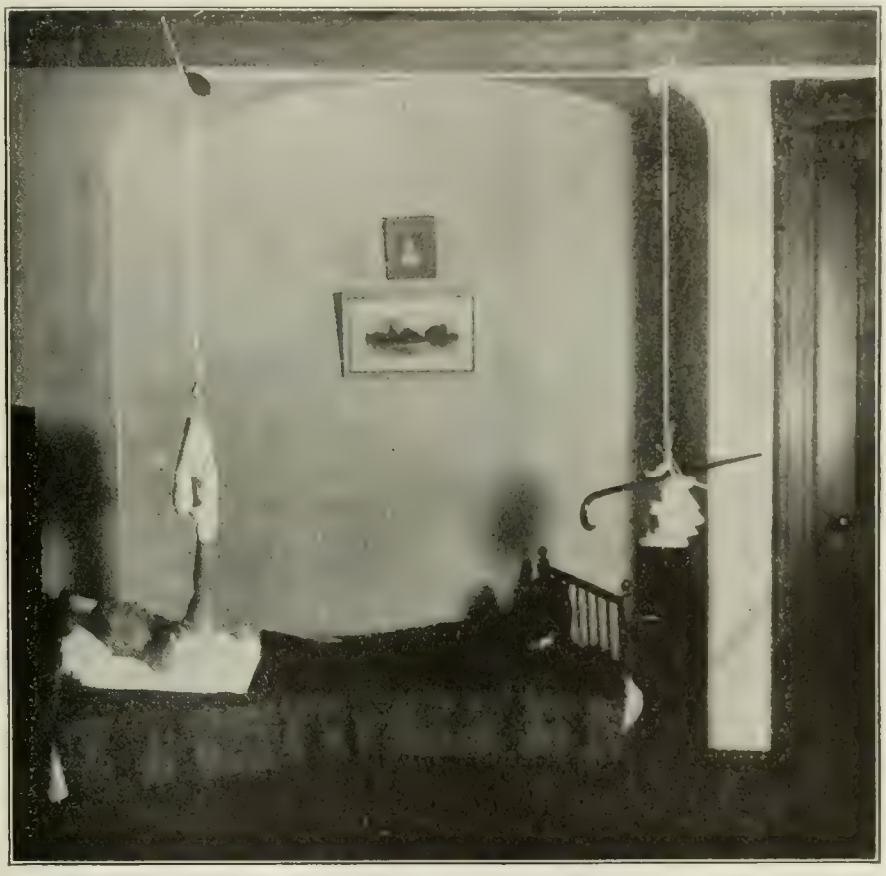


FIG. 2587.—Torsional Suspension of the Right Forearm. Note that the torsion of the suspension cable maintains full supination of the forearm. The untwisting of the cable is prevented by the impinging of the end of the walking stick against the corner of the alcove. This cable is extemporized from three strands of braided sashcord twisted in the opposite direction from an ordinary rope. For supination of the left forearm an ordinary three-quarter inch rope may be used.

The two characteristic deformities we have mentioned are caused by a combination of the sliding and the tilting displacement, in a backward and outward direction. The displacement of the lower fragment upward is chiefly due to impaction; this may be measured in part by the position of the radial with reference to that of the ulnar styloid process, though a considerable proportion of this deformity is due to the displacement by tilting. In the normal wrist the tip of the radial styloid lies about a quarter of an inch lower than that of the ulnar styloid; if the two are at the same level, or if the radial styloid is the higher, fracture of the radius is probably present. The comparison must be made with the hand in supination, as in pronation the examining finger on the inner side strikes upon the head of the ulna and not upon its styloid process.

The first essential in the treatment of Colles' fracture is accurate reduction, and this can only be obtained when the impaction, which is present in greater

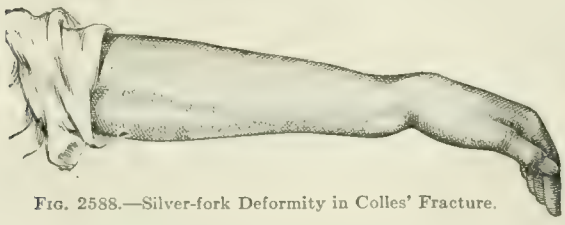


Fig. 2588.—Silver-fork Deformity in Colles' Fracture.

or less degree in a majority of the cases, has been completely loosened. To this end anesthesia is in all cases desirable, and in most cases indispensable, not only to subdue the pain of the forcible manipula-

Fig. 2589.—The Anatomical Basis of the Silver-fork Deformity. (Scudder.)

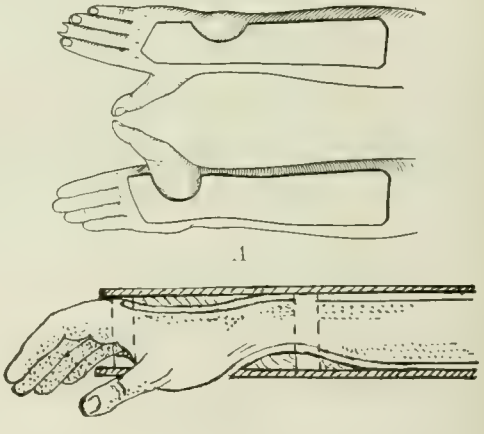
tion which a proper reduction generally requires, but, what is still more important for the success of the reduction, to abolish the contractility of the forearm muscles. As is very commonly the case in freeing

Fig. 2590.—Radial Deflection of the Hand in Colles' Fracture. Note the abduction of the little finger. (Helferich.)

impactions and in reducing dislocations, the first movement in the reduction of an impacted Colles' fracture should be an application of force in the same direction which caused the lesion in the first place. The typical Colles' fracture is caused by hyperextension, and forced hyperextension of the wrist is the maneuver generally best calculated to loosen the impaction. The novice will hardly appreciate the degree to which it is well to hyperextend the wrist in order to set the impacted fragments sufficiently free to make possible their satisfactory reduction. The normal wrist can be extended to such a point as

Fig. 2591.—Reposition of Lower Fragment after Breaking up Impaction by Forced Hyperextension.

will bring the dorsum of the hand to a right angle with the axis of the forearm, and it is not until this right angle has been passed that we begin to move the lower fragment upon the shaft of the radius. Forced extension then, until the dorsum of the hand forms an acute angle with the radial shaft, should generally be the first step toward reduction. When the impaction has been loosened by forced extension, aided, if need be, by forced abduction and adduction of the hand, both thumbs should be applied to the back of the distal fragment, with the fingers on the anterior side of the wrist, and by the pressure of the thumbs the lower fragment should be forced forward into its place. When the upward and backward displacement is deemed to have been sufficiently corrected, it is well to grasp the hand of the patient as in shaking hands, and to perform full circumduction, to free the capsule of the wrist-joint from any possible entanglement on the head of the ulna, whose styloid process is not infrequently broken at the time of the fracture of the radius. It is also well, after the pre-



B

Fig. 2592.—*A*, Board Splints for Colles' Fracture Patterned according to Cotton; *B*, Same padded and adjusted.

vious maneuvers, to flex the wrist strongly for the purpose of correcting that special element of the displacement which is due to backward tilting. Mere downward traction in the axis of the forearm, no matter how forcible, should never be relied upon for the setting of a Colles' fracture, as it is not often possible, without the various bendings advised, to loosen the impaction and restore the fragments to their normal position. When the fracture is reduced

it can best be retained by anteroposterior board splints, properly cut away to avoid pressure on the thenar eminence anteriorly and on the lower end of the ulna posteriorly, and properly padded to give pressure upon the radial arch anteriorly, and upon the dorsum of the wrist and of the hand posteriorly. The splints should not be long enough to impede the flexion of the elbow above, nor should they extend beyond the base of the metacarpals below; it is not necessary, as in fractures of the shaft of the bones of the forearm, that the splints should be broader than the diameter of the forearm, as there is little danger of lateral pressure from the encircling bandages causing any encroachment on the width of the interosseous space. The splints should be fastened in their proper position with strips of adhesive plaster, and the hand and the forearm should be bandaged over all. It should be strictly enjoined upon the patient to keep constantly flexing and extending the fingers, both actively and passively, even at the cost of a little pain. Daily inspection of the dressing should be the rule for the first week, at the end of which time, or shortly thereafter, it is well to remove the anterior splint and to keep the hand, wrist and forearm supported by plaster strips and by bandages against the posterior splint. The second splint can generally be safely left off after two or two and a half weeks, the sooner the better, and such support as the wrist still requires can be afforded by a three-inch band of adhesive plaster encircling the wrist at the site of the fracture. Active and passive movements of the wrist should be encouraged as soon as the splints are removed, but the hand should not be put to any use in lifting for about four weeks, and the use of the hand should be very guarded for six or seven weeks from the time of the accident. Any considerable pain in the fracture, for more than forty-eight hours after the reduction, is *prima facie* evidence that the reduction was imperfect, and would render the use of the *x*-ray most desirable

Fig. 2593.—Fracture of Carpal Scaphoid from a Fall on the Hand (Whitelocke.)

Fractures of the Carpal Bones.—Fractures of the bones of the carpus, with the exception of those of the scaphoid, are mostly due to direct violence and are received in crushing accidents or from explosions or gunshot wounds. Fractures of the scaphoid, however, result generally from a force similar to that which commonly causes a Colles' fracture of the radius. This lesion must be suspected where a lesion of the wrist has been received from such a force, when actual Colles' fracture can be excluded on careful examination, as the results of treating a scaphoid fracture as a sprain of the wrist, and subjecting it to massage, counterirritation and hot air, to exclusion of the needful immobilization, are likely to be most

Fig. 2594.—Hand Strapped over Tennis ball. Dressing for fracture of the second metacarpal. The completed dressing would require bandaging of the hand to hold the adhesive strips in place. The thumb may be left at large.

unsatisfactory. Excision of one fragment is good treatment in cases which have failed to form at least a firm fibrous union in four or five weeks. This can be done without materially interfering with the function of the joint. The joint function is however seriously compromised when the whole of the scaphoid is resected.

Fractures of the Metacarpals.—In fractures of the shaft of the metacarpal bones it is necessary to avoid dorsal displacement, on account of the vulnerability of any projecting boss on the back of the hand. It is still more important to avoid any palmar displacement, on account of the hindrance to a firm grasp upon the handle of tools and like objects. The best treatment is by strapping the hand and fingers upon a ball somewhat smaller than a baseball. The same treatment is applicable also to fractures of the base of the metacarpals, "knuckle fractures," though the importance of slight palmar displacement, which it is very difficult to avoid, is less considerable than in the case of fractures of the shaft of these bones. The metacarpal of the thumb is subject to a greater variety of fractures than are the rest of the metacarpals, one in particular, known as a Bennet's fracture, or as a "stave of the thumb," affects the proximal end of the bone, and is of the nature of a flexion fracture (see Fig. 2543), whose characteristics have been discussed when treating of supracondylar fractures of the humerus. Goldthwaite has devised a simple and ingenious thumb splint which is serviceable in the treatment of these not uncommon fractures.

Fractures of the Fingers.—Fractures of the phalanges are generally caused by direct violence. The fascial and periosteal investment of these bones is so firm that fracture often occurs without easily recognizable displacement. Simple palmar and dorsal splints are easily rigged for their treatment.

Fractures of the Femur.—Fractures of the femur are most conveniently divided into those of the upper end, those of the shaft and those of the lower end of the bone.

The fractures at the upper end of the femur are of four general types, namely, fractures of the femoral

neck, close to the head (subcapital fractures), fractures at the base of the femoral neck, more or less along the intertrochanteric line, fractures more or less in the frontal plane through the trochanteric masses (pertrochanteric fractures), and fractures below the great trochanter yet above the lesser trochanter,

Fig. 2595.—Bennett's "Stave of the Thumb". Note the typical features of a flexion fracture. (Whitelocke.)

more or less horizontal in the plane of their fracture (subtrochanteric fractures). In addition to these more typical forms of fracture we have also fractures of intermediate type between the subcapital and those more exactly along the intertrochanteric line, we have also V-fractures and Y-fractures, a combination of the pertrochanteric type and that of those at the base of the neck, or a combination of the pertro-

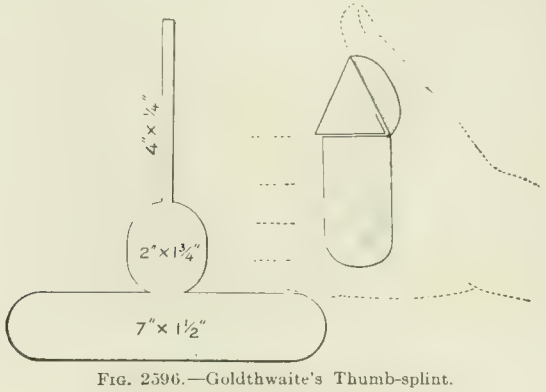


Fig. 2596.—Goldthwaite's Thumb-splint.

chanteric type with subtrochanteric fracture, and finally we meet occasionally with isolated fracture of the great trochanter, and, as a great rarity, with isolated fracture of the lesser trochanter.

Subcapital Fractures.—Subcapital fractures are most common in old age, and particularly in old women, the reason for this being the strong predisposition thereto from senile atrophy of the intrinsic structure of the bone; indeed, so slight a degree of violence will often suffice to produce a subcapital fracture that fractures of this type may fairly be regarded as virtually pathological fractures. Yet is their occurrence by no means restricted to old age, and in children what is virtually the same fracture is met with in the form of an epiphyseolysis. This fracture presents, in all cases which are not impacted, and impaction of a subcapital fracture is the rare exception, an unfavorable prognosis as to bony union, and in the aged, an uncertain prognosis as to life, the fracture in the aged being very frequently followed by pneumonia. The reasons why bony union rarely follows this fracture are several; in the first place, there is almost constantly an eversion of the limb, due, in part at

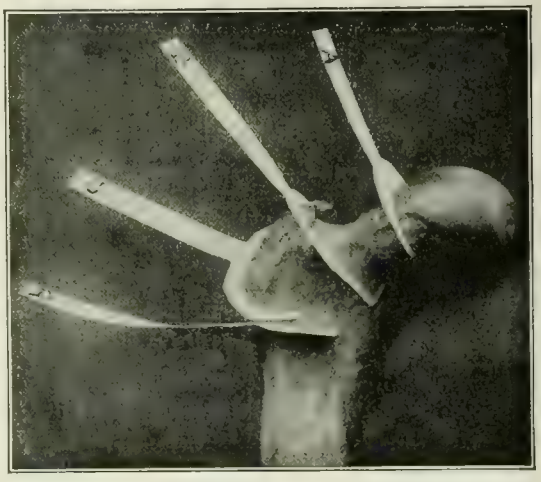


Fig. 2597.—Lines of Fracture through the Upper End of the Femur. *A*, subcapital fracture; *B*, fracture at the base of the neck; *C*, pertrochanteric fracture; note that it is in the frontal rather than in the sagittal plane; *D*, subtrochanteric fracture.

least, to the superior power of the external over the internal rotators, and this is difficult of sufficiently accurate correction to permit of sufficiently close apposition of the fragments to favor bony union where the reparative material is so scantily thrown out as is the case in any intracapsular fracture. In the second, place the break lies so deep under the tissues, and the upper fragment is so small, that it is impossible to secure any exact fixation. In the third place, the blood supply to the femoral head is scanty at best in the atrophic bones which are generally the subject of this fracture, and the small vessels in the ligamentum teres are inadequate to keep up that exaggerated type of nutrition which proper bone repair demands. Finally, and perhaps most important of all, the presence of the joint capsule between the fractured bone and the surrounding soft parts prevents the latter from furnishing their quota of reparative material for the building up of an adequate provisional callus.

In view of all these attendant disadvantages it is sometimes wise, in aged and feeble subjects, to give up, at the start, any strenuous efforts to obtain by fixation and recumbency a good surgical result in the healing of the fracture, and to direct all our attention to the vital indications exclusively, contriving by pillows and other convenient supports to keep the injured limb as comfortable as possible, and getting the patient out of bed, and into an easy chair, as soon as the active and painful inflammatory symptoms have somewhat subsided. For some cases it has been recommended to pin the head to the femoral neck by

means of long screws or nails driven in through the trochanteric mass. This procedure is but rarely advisable, and if it were to be practised, it would seem, in the light of modern experience with bone grafts, to be advisable to substitute for the nails or screws slender rods of bone taken from the tibia of the

Fig. 2598.—Fixation of the Femoral Head. (Keen.)

patient, or if opportunity offered, from the tibia of another individual. The treatment of the case by virtually ignoring the fracture, and the treatment by transfixion through the trochanteric masses is applicable to but a small minority of cases. Subcapital fractures are generally best treated by vigorous

generally required in the treatment of fractures of the lower extremity that it will be wise to describe it in some detail. Both for the Buck's extension and for the more useful Hodgen's splint the first steps are the same. The limb should first be shaved and be rendered aseptic, so as to permit the adhesive strips to remain in place all through the treatment if possible without causing a dermatitis. Four strips of adhesive plaster, about three inches wide, and long enough to reach from the level of the perineum to about sixteen inches below the sole of the foot, should be applied, as shown in the figure, two to each side of the leg and thigh. They should overlie each other in their lower portion, so as to give a double thickness

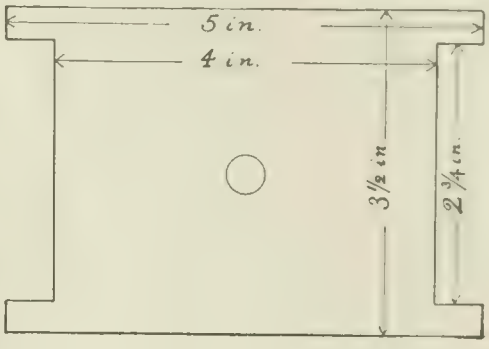


Fig. 2600.—Spreader.

of plaster in that part which lies below the ankle. These strips should be applied as neatly as possible, so as to be free from wrinkles. A two-inch roller bandage should then be applied to the foot and ankle, a thick pad of folded gauze being placed over the tendo Achillis, and when the turns of the bandage have reached the level of the ankle the bandage should be continued up the limb as far as the level of the perineum, on the outside of the plaster strips; the object of the lower part of the bandage being to prevent swelling of the foot and ankle, and the object of the upper part of the bandage being to hold the plaster closely applied to the skin. A wooden

Fig. 2599.—Adhesive Strips for Extension Apparatus of the Thigh

and prolonged extension, preferably through the means of a Hodgen's splint, though many still make use of the less comfortable and less efficacious Buck's extension.

The application of an extension apparatus is so

spreader should next be prepared, of the shape and dimensions shown in the diagram, and over this spreader the adhesive strips should be fastened. The most satisfactory way to fasten the strips to the spreader is to cut the strips longitudinally with

scissors in such fashion as to leave a central strip two and a half inches wide, which central strips are to be crossed on the distal surface of the spreader, while the lateral strips are to be brought one to the top edge and the other to the bottom edge of the spreader where they are of considerable service in steadying the

Fig. 2601.—Adjustment of Adhesive Strips to Spreader. On the outer side of the foot the anterior marginal strip has been made completely fast to the spreader while the posterior marginal strip, is just being applied. On the inner side of the foot the marginal strips pass above the upper and below the lower edge of the spreader but have not yet been applied to the wood. These marginal strips serve to hold the spreader perpendicular to the axis of the leg.

spreader in its proper position, which should not be parallel to the sole, but rather perpendicular to the axis of the leg. The adhesive plaster strips, thus adjusted over the spreader, can now be connected with a simple traction cable run over a pulley and attached to a weight, or can more advantageously be attached to a Hodgen's splint.

The framework for a Hodgen's splint can be readily improvised out of telegraph wire, or can be somewhat more neatly made from quarter-inch iron rod. If telegraph wire is used the wire will have to be doubled and be whipped with strips of adhesive plaster in order to give it the required strength. The frame of Hodgen's splint consists of a proper wire or iron rod, bent so as to afford an internal and an external support, reaching from about five inches below the sole of the foot to the level of the perineum, and a connecting piece below the sole about six inches long. To the upper end of the frame is to be made fast a half hoop of iron, of such a spread as to keep the upper arms of the frame asunder a distance about an inch greater than the greatest diameter of the thigh. The arms of the frame should be bent, at the level of the knee, to an angle of fifteen, twenty, or more degrees, according to the amount of flexion we wish to maintain in that joint. The frame, as constructed of telegraph wire, and ready to be fastened together with a lashing of adhesive plaster, is shown in the accompanying figure. To the inner branch of the frame are next to be made fast eight to twelve strips of bandage, long enough to permit them to pass under the limb, and to be made fast to the outer branch of the frame, with a convenient degree of tension. When the frame is thus prepared and is equipped with its strips of bandage it should be laid over the injured limb, and the bandage strips should one by one be passed under the limb till they are all smoothly in place. The injured limb should now be raised from the bed, and upon the orderly disposed strips of bandage should be laid a sheet, so folded as to reach from the ankle to the perineum, and of a width about half the circumference of the thigh. When this sheet has been evenly disposed beneath the limb, this should be lowered to lie upon it, and the several bandage strips should be drawn up and fastened to the outer branch of the frame, the bandage strips collectively forming a sling which shall hang the limb to the frame.

The Hodgen's splint is now ready for the application of its special and remarkably adjustable suspension and traction cords. The first of these is the "extension cord" which after having been knotted at one end is passed through the hole in the wooden spreader below the sole, and is to be made fast to the crosspiece of the frame, and should be tied there at such a length as to bring the inner branch of the frame clear up to the perineum. Two "balancing cords," about four feet long, should be fastened, at one end, to the upper end of each branch of the frame; they should then cross each other, and the other end of the inner cord should be made fast to the outer branch of the frame and that of the outer cord should be made fast to the inner branch of the frame, both at about a handsbreadth below the level of the tibial tuberosity. The points of attachment should be exactly symmetrical on the two sides, and the two "balancing cords" should be so tied as to be exactly equal in length.

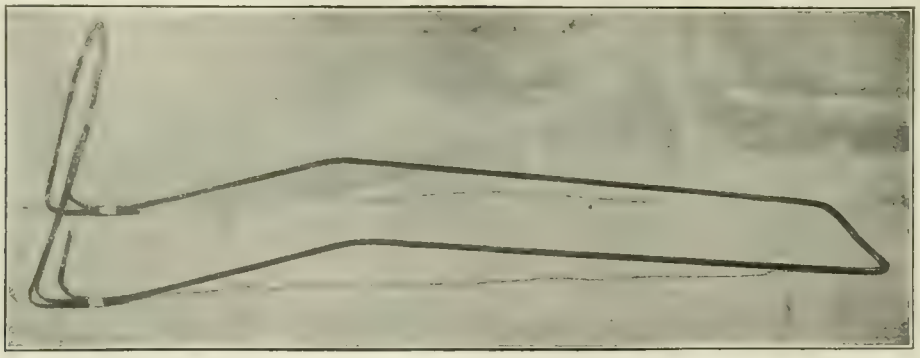


Fig. 2602.—Frame of Hodgen's Splint.

Through the "bight" of the obliquely crossing "balancing cords" should now be passed the end of the "traction cable," which should be tied in some knot that will not draw down tight to prevent the easy play of the "balancing cords" through the knot, and the "traction cable" should then be passed

through a pulley in the ceiling, placed at such a distance beyond the foot of the bed as to allow the weight to which it is to be attached, to swing free of the foot of the bed, and to cause the "traction cable" to draw at an angle of about 60° from the horizontal.

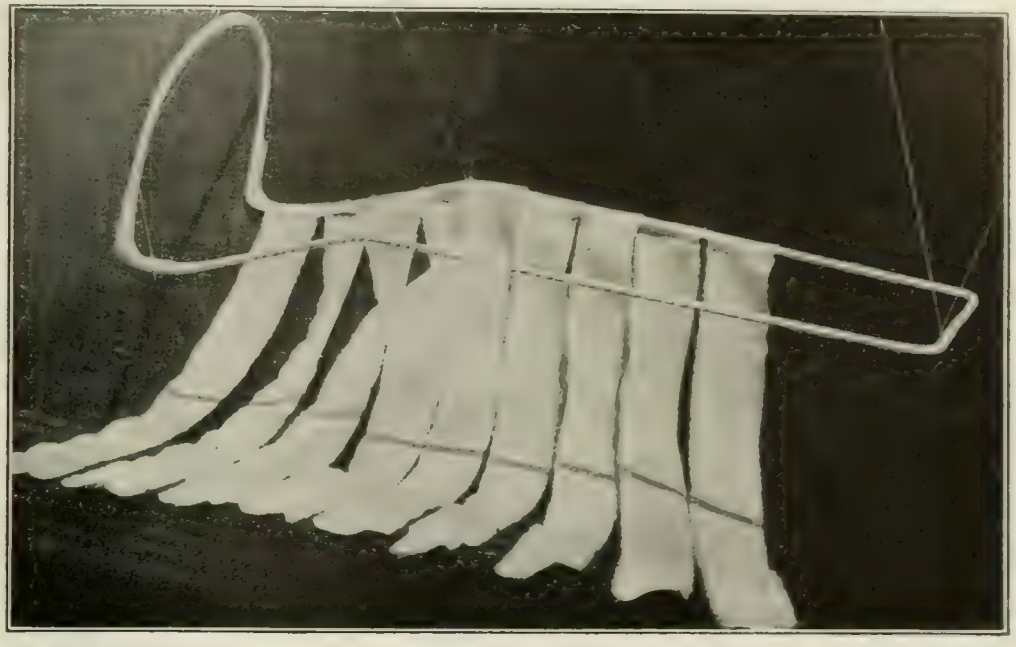


Fig. 2603.—Frame of Hodgen's Splint Whipped with Adhesive Plaster, and Showing Bandage Strips Fastened to Inner Side

The raising of the foot of the bed will afford counter-traction. The foot should be lifted constantly just clear of the bed, and it is important to bear in mind that this clearance is indispensable to the proper functioning of the apparatus. With this apparatus the use of the bedpan is greatly facilitated, and the patient can be rolled, without difficulty and without damage, on the sound side, for the changing of the linen and for the proper care of the back. After but a few days, to allow the subsidence of the inflammation and pain, the patient may be propped up into a sitting posture without disturbing the fracture.

Fractures at the Base of the Neck of the Femur.—Fractures of the base of the femoral neck occur indeed with somewhat greater frequency in the aged, but they are by no means so largely confined to that age as are subcapital fractures. They are occasioned by force applied in the axis of the femoral shaft, as in a fall on the knee, or by force applied to the trochanteric region. These fractures are much more frequently impacted than are subcapital fractures, and this impaction has not infrequently been found so firm as to have permitted the patient to take at least a few painful steps after the fracture, and even, in rare instances, to have walked some little distance; even a

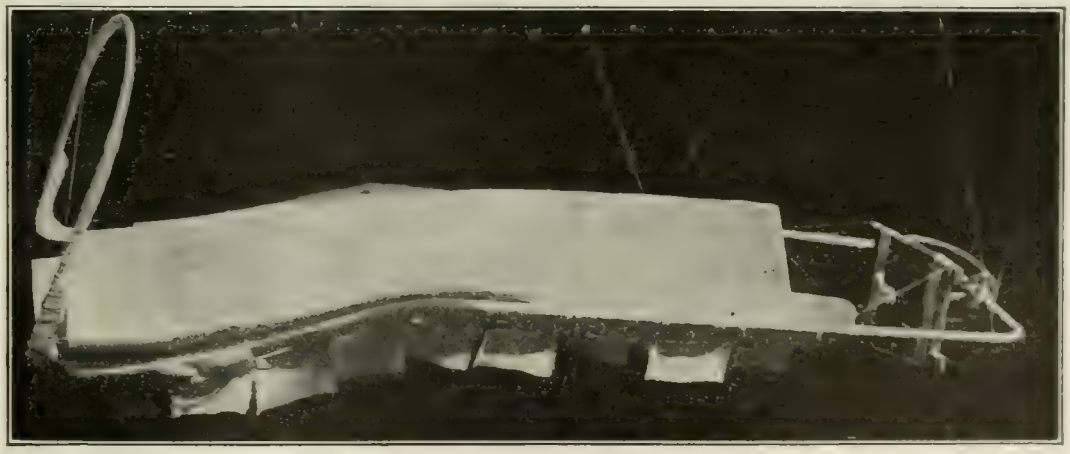


Fig. 2604.—Hodgen's Splint, Showing Bandage Strips Which Were Sewed to Inner Side, Brought Across and Fastened to Outer Side with Safety Pins. Upon these strips is laid a folded sheet. The spreader is shown with the extension cord attached at the end and made fast to the cross piece.

slight degree of impaction will permit the recumbent patient to rotate the foot to some extent, but one movement is almost invariably impossible of execution, namely the lifting of the heel free from the bed, even when some limited degree of flexion of the thigh is possible. When there is no impaction, the lifting of the foot clear of the bed, is of course impossible, owing to the want of support to the upper end of the femoral shaft, when impaction is present, the pain caused by pressing together the fractured surfaces inhibits the movement.

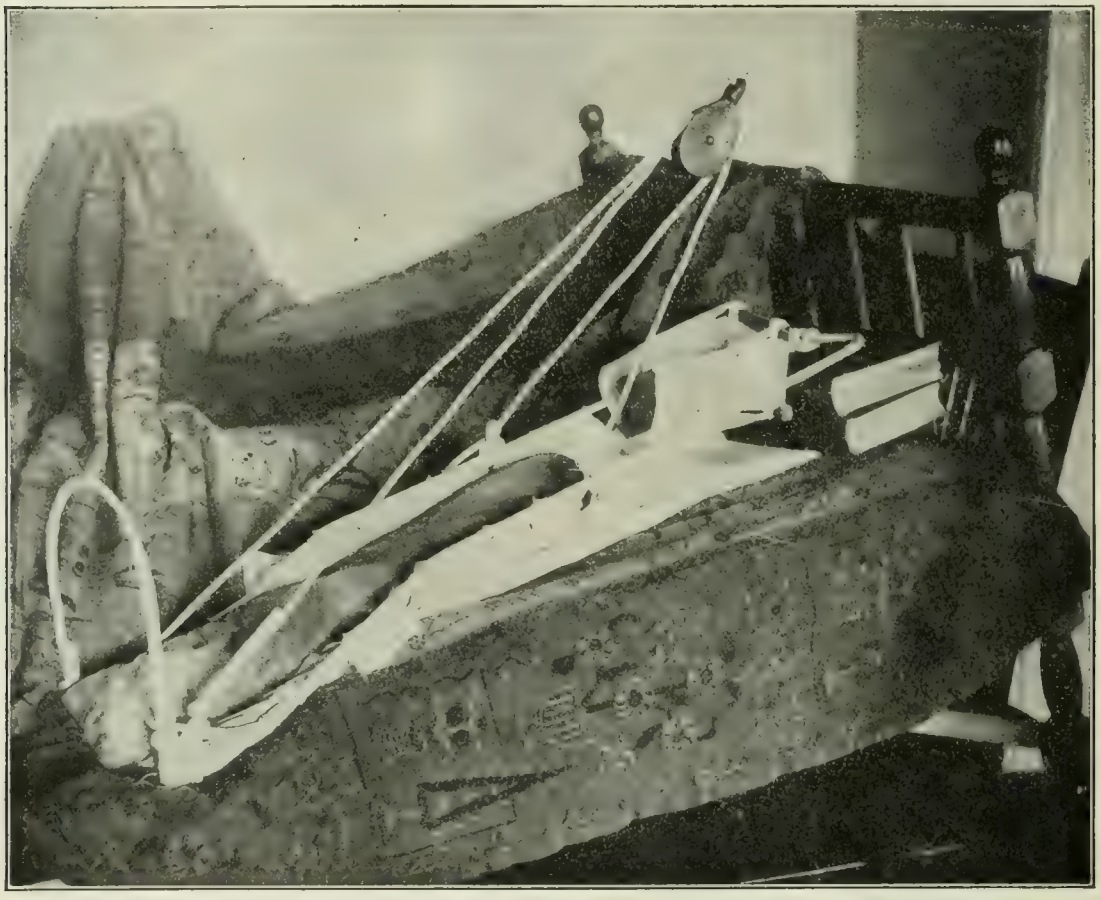


Fig. 2605.—Hodgen's Splint with "Balancing Cords" and "Traction Cable." The "extension cord" and spreader are also shown A sand bag is used to hold the apparatus in position for the photographer.

The diagnosis of fracture of the neck of the femur is based upon the following signs. There is almost always a demonstrable degree of shortening. In impacted fractures this shortening may not, at first, be very considerable, but it increases hour by hour, not so much by the fragments gliding past each other, as is the case where there is no impaction, as by a progressive decrease in the angle between the neck and the shaft of the bone. The limb, in contradistinction to luxation of the hip, is generally extended, and lies parallel to its fellow. The foot is generally everted, and, where there is no impaction, the patient is incapable of correcting the eversion by voluntary effort. To the extended position of the leg and to eversion of the foot there are occasional exceptions. The active functions of the limb are generally totally abolished, but a certain remnant of the power to flex and to rotate the limb may be retained where there is impaction. In contradistinction to the completeness of the abolition of active function is the possibility of passive motion in all directions, and generally, within certain limits, without pain, this is quite different from what is found in dislocation of the hip, where the placing of the extended limbs side by side is impossible until the dislocation has been reduced. Pain, when present, and tenderness, when found, are generally in Scarpa's triangle. It is occasionally possible when the fracture is way out at the intertrochanteric line, to determine that when the limb is revolved on its axis the femoral neck does not share in the motion, and the great trochanter revolves with the shaft without describing the arc of a circle whose radius is the length of the femoral neck; when the fracture is somewhat nearer the head this sign is not easy to discern. All fractures of the femoral neck, with the exception of subcapital fractures, are, in at least a part of their extent, extracapsular fractures, and non-union, from the deficiency of reparative material, is consequently much more rarely encountered. On this account there need be less hesitation in breaking up an existing impaction, as bony union is much less dependent upon this means of maintaining apposition of the fragments than is the case in subcapital fractures.

The treatment most generally advocated for fracture of the femoral neck is by long-continued traction with heavy weights, applied most conveniently and most comfortably by means of a Hodgen's splint. In cases where it is deemed wise not to disturb an

Fig. 2606.—Hodgen's Splint Applied. The foot swings free above the bed.

existing impaction these weights need not be so heavy nor their use so long continued, but their use is generally advisable, even in cases of firm impaction, on account of the tendency to progressive shortening, due to bending of the neck upon the shaft through the site of the fracture. Other methods of treatment are by ambulatory apparatus such as the Thomas' hip splint, by fixation in a plaster-of-Paris spica, and by pegging, according to the method suggested above in discussing the treatment of subcapital fractures. A new method of treatment suggested by Royal Whitman, of New York, has found some ardent advocates. This method of treatment rests upon these assumptions: (a) that the most constant displacement in fractures of the base of the femoral neck is a displacement downward, with lessening of the normal angle between the neck and the shaft, and that this is the chief cause of shortening of the limb in these fractures, and not longitudinal translation of the fragments one on the other; (b) that traction *per se*, at least in impacted cases, has very little tendency, no matter how great the weight, to do away with this shortening, by restoring the diminished angle; (c) that it is better, therefore, to loosen the impaction, and to reduce the fracture under ether; and (d) that an efficient *point d'appui* can be found in abducting the thigh until the tip of the great trochanter impinges on the upper border of the acetabulum, against which it can be pressed sufficiently to maintain correct tion of the angle by putting up the limb in abduction in a double plaster-of-Paris spica, which maintains the opposite limb likewise in a position of full abduction. The method has not been long enough before the profession to have its merits fully tested. The conception is a logical one and its author claims satisfactory results.

Fig. 2607.—Diagrammatic Sketch Showing Recent Fracture at the Base of the Femoral Neck with Impaction.

Fig. 2608. Increase of Shortening through Decrease of Angle between Shaft and Neck. (Keen.)

Pertrochanteric and Subtrochanteric Fractures.—Pertrochanteric fractures are much less common than are fractures of the femoral neck. They are generally the result of a considerable degree of violence, applied directly to the trochanteric region, or of a fall on the buttocks from a considerable height. Their distinguishing characteristic, beyond the fact that they transverse the general trochanteric mass, is their lying in a frontal rather than a sagittal plane. They quite frequently show impaction. The position of the limb and the eversion of the foot are substantially as in fractures of the femoral neck, but the degree of shortening is apt to be greater. These fractures are further distinguished by distinct tenderness in the region of the trochanter, in the outer portion of Scarpa's triangle, and in the digital fossa, behind the trochanter major. They are also apt to show very promptly a considerable effusion of blood, due to the fracture running through a more vascular portion of the bone, and this effusion is apt to show itself as an ecchymosis extending down the outer portion of the thigh. On rotating the limb on its axis, the trochanter major will not follow the motion of the shaft, unless there is a certain degree of impaction. The treatment should be substantially along the lines recommended for fracture of the femoral neck.

Fig. 2609.—Principle of Whitman's Method of Treatment by Forced Abduction.

Fig. 2610.—Pertrochanteric Fracture Running Nearly in Frontal Plane. (Kocher.)

When we come to subtrochanteric fractures, which have much the same causes and quite similar symptoms to pertrochanteric fractures, a further element has to be considered in the treatment, namely, the effect of the gluteus medius and minimus, and of the short pelviofemoral muscles in causing the displacement of the upper fragment. By the combined action of these muscles the upper fragment is drawn into a position of abduction and external rotation, and the traction which is demanded for the treatment of the fracture should be applied in a direction to accommodate the position of the shaft to that of the upper fragment. These fractures are generally more or less directly transverse.

Fig. 2611.—Abduction and External Rotation of Upper Fragment in Subtrochanteric Fracture. (Kocher.)

Y-fractures and L-fractures are the result of more considerable violence than is required to produce the simpler fractures we have been considering. While their prognosis is more grave, and satisfactory restoration of function is more uncertain, the principles of treatment are the same as for the simpler fractures of this region.

Isolated fracture of the trochanter major is rare, it involves abolition of the function of abduction in large measure. The fracture is difficult of recognition without the help of the *x*-ray, unless, as rarely happens, a considerable portion of bone is carried away. The best treatment is by direct fixation with suture, the thigh being afterward put up in abduction in a plaster-of-Paris spica.

Fig. 2612.—Y-fracture of Upper End of Femur. (Kocher.)

Fractures of the Shaft of the Femur.—In fractures of the shaft of the femur we have to contend against

a strong tendency to displacement from the action of the most powerful muscles of the body. Fracture may occur anywhere in the femoral shaft, but these fractures, while they are occasionally more or less

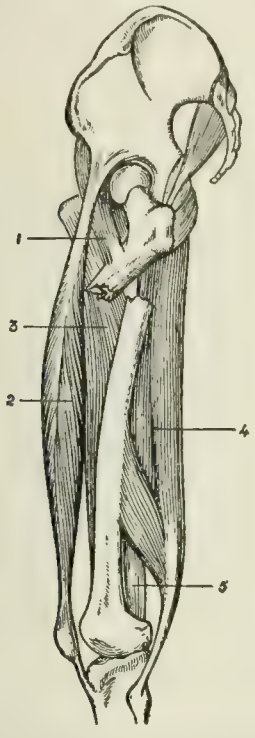


Fig. 2613.—Muscles Acting on Upper Fragment in Fractures High in the Femoral Shaft. The position of the upper fragment is one of flexion, abduction, and external rotation. 1. Iliopsoas tendon; 2, rectus; 3, adductors; 4, triceps; 5, inner hamstring tendon. (Rose and Carless.)

nearly transverse, are apt to exhibit a marked degree of obliquity and are not infrequently spiral fractures; the oblique and the spiral fractures are notoriously difficult to retain in proper position after reduction. In fractures of the upper third we have to pay special attention to the position assumed by the upper frag-

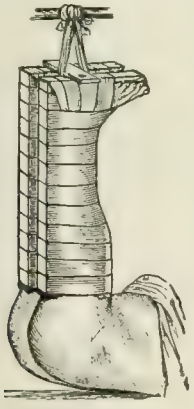


Fig. 2614.—Vertical Suspension for Fracture of Femur in Children. (Bryant.)

ment under the influence of the attached muscles, and the traction, which is almost always indicated in the treatment, should be applied in a direction and in a manner calculated to bring the axis of the shaft into line, as far as possible, with the axis of the upper fragment. To this end it is not infrequently necessary to apply the traction with the thigh in a certain degree of flexion on the trunk, as well as in a certain degree of abduction, and occasionally it may be necessary to make simultaneously lateral and longitudinal traction on the limb; furthermore it may be necessary to have the knee more or less flexed. These varied requirements can generally be met with the use of the Hodgen's splint, with such modifications and adaptations as the particular fracture demands. The fragments can advantageously, in most cases, be steadied by coaptation splints, which however should be short enough not to make pressure on any of the bony prominences of the femur, as their function is simply that of steadying the fragments of the broken shaft, and is not that of supporting the fractured limb as a whole. In children vertical suspension of the injured limb is preferable to other forms of traction.

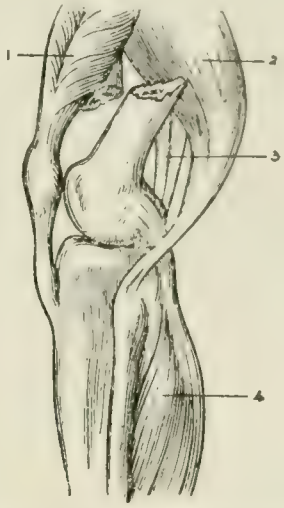


Fig. 2615.—Flexion of Lower Fragment in Supracondylar Fracture of Femur, through Action of the Gastrocnemii. Note that this lesion has all the attributes of a flexion fracture. (Dennis.)

Fractures of the lower end of the femur occur in the forms of supracondylar fracture of the general type of a flexion fracture, epiphyseolysis, the only representative of an extension fracture in this region, T-fractures into the knee-joint and isolated fracture of either condyle.

Supracondylar Fractures of the Femur.—In supracondylar fracture of the lower end of the femur there is a certain tendency, probably not so constant as has been customarily taught in the text-books, for the lower fragment to be tipped backward under the action of the gastrocnemii, and to work great damage to the popliteal vessels and nerves. Whether this angular deformity exists as an actuality or only as a tendency, it is necessary to take account of it in the treatment, as malunion in angular deformity will seriously interfere with the function of the limb. In view of this tendency to flexion, the fractured limb should never be treated with the knee extended. The limb can best be treated by the use of a double inclined plane or by traction applied over an angular popliteal splint.

In the adult, extension fracture of the lower end of the femur does not occur, for the reason that hyperextension leads to rupture of the posterior portion of the capsular ligament and to dislocation of the knee, before the bone yields. In children, however, hyperextension will cause a separation of the epiphysis, with displacements which are often extremely difficult to reduce, and which may work such havoc to the

structures in the popliteal space that primary amputation remains the only practical method of treatment. Where the popliteal structures are not hopelessly injured a forward displacement of the epiphysis can be generally reduced under an anesthetic by firm pressure of the thumbs during strong traction on the flexed lower leg, by an assistant, in the line of the femoral axis. Backward displacements are still more difficult to reduce, they demand the traction on the flexed leg, as above described, and in addition firm upward traction on the lower end of the femoral shaft, at a right angle to the traction which is being exercised on the lower leg. Not infrequently it is necessary to intervene with levers, introduced through an open

Fig. 2616.—Traction over an Angular Popliteal Splint. Note that the splint is not made fast to the thigh. The outline of the lower portion of the splint is indicated upon the bandage.

incision, to accomplish the reposition. When once reduced the tendency to redisplacement is small and the prognosis is good, but the lesion carries with it a very high primary mortality.

T-fractures of the lower end of the femur are in many ways analogous to T-fractures of the lower end of the humerus. They are caused by great violence applied to the knee. Their diagnosis is made by maneuvers developing the same factors, namely hyperextension, abduction, adduction and crepitation, as were reviewed in considering the diagnosis of the homologous fractures of the humerus. The effusion into the knee-joint will be very considerable, and independent mobility of the condyles upon the shaft of the femur, and upon each other, will be demonstrable as in the corresponding humeral fractures. In view of the probability of permanent ankylosis it is generally best to treat such fractures in the extended position of the leg. The ankylosis it may be possible to correct by the more modern operations of tissue interposition. The straight position of the leg it is important to maintain. Traction on the lower leg will do a great deal to mitigate the pain of this extremely severe lesion and to favor good union.

Fracture of either condyle alone may be a result of a fall on the feet with an added strain of adduction, to cause fracture of the internal condyle, or of abduction, to cause fracture of the external condyle. The limb, in treatment, should be fixed in a position just short of complete extension.

In supracondylar fractures, in epiphyseolysis, and in fractures of one or of both condyles the concomitant traumatic arthritis is a matter of nearly as great moment as the fracture, and in the unfortunate event of a septic infection of the site of the fracture, a suppurative arthritis of the knee is pretty sure to follow, entailing a vast degree of suffering and of danger.

Besides the fractures of the lower end of the femur already enumerated, we meet, not infrequently with fractures of either epicondyle, as a complication of sprain of the knee. These fractures are highly important, from the fact that the epicondyles bear the insertions of the lateral ligaments of the joint, and although the fractures present less general gravity than do the fractures we have already discussed, yet if these lesions are unrecognized, and fail to receive the treatment by prolonged fixation, which is proper to a true fracture, they are likely to result in a permanent weak knee, through imperfect support from the lateral ligaments of the joint.

Fractures of the Patella.—Fractures of the patella occur in two forms which have a different etiology. The first form is more rare; the cause is

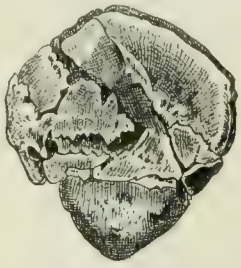


Fig. 2617.—Stellate Frature of the Patella from Direct Violence. (Internat. Textb. of Surgery.)

direct violence to the patella and the bone is shattered in various directions, forming what is known as a stellate fracture. As a rule comminuted fractures are considerably more serious than are simple fractures, but in this case the peculiar function of the patella as a sesamoid bone makes the stellate fracture interfere much less seriously with its function than does the simple transverse fracture, which is generally the result of leverage upon the patella when poised upon the femur in partial flexion, though it is occasionally brought about by pure avulsion. In the stellate fracture the thick, tough fibrous periosteum on the anterior surface of the bone is rarely torn completely across, for all that the bone is comminuted, and in consequence there is but little tendency to the diastasis of the fragments. which is so important a

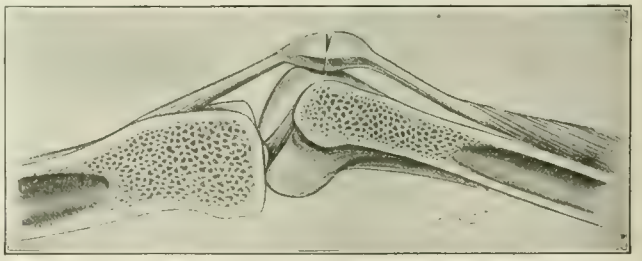


Fig. 2618.—The Common Mechanism of Fracture of the Patella. This cannot occur while the patella occupies its proper position in the intercondylar groove; but when the patella rides upon the external condyle in slight outward subluxation, it is readily fractured by infraction or bending over the underlying femoral condyle.

factor in the transverse fractures. The treatment of stellate fractures of the patella should accordingly be generally a conservative one, the leg being kept in full extension until the fragments have time to unite. In transverse fractures of the patella, on the other hand, the displacement of the fragment is the rule. And, it should be remembered, in deciding upon what

line of treatment to adopt, that the displacement is not generally a simple diastasis, but a more complex displacement, involving a tipping of one or of both fragments forward or backward, and not infrequently a wider diastasis at one side than at the other side of the bone. The result of the ordinary complexity of the displacement is that when the fragments are approximated as nearly as is possible by the extension of the knee and by traction on the fragments, there is apt still to remain a considerable interval between certain portions of the fragments, even if they be

Fig. 2619.—displacement of Fractured Patella not a simple Diastasis and not Completely Reduced by Muscular Relaxation. The hiatus is always too great in conservative treatment to be filled out by bone tissue and fibrous union must result. (International Textbook of Surgery.)

made to touch at certain points. The result is that bony union can hardly be hoped for by conservative treatment, and that the fibrous bond, even when close at the time the treatment is discontinued, tends to lengthen under the use of the limb, to an extent which it is difficult to foretell, and this may bring with it a disability which may be very disappointing alike to the patient and to the surgeon. Where there is no special counterindication, wiring affords by far the better results, and requires an after-treatment very much less prolonged than is necessary for treatment by fixation alone.

Fractures of the Lower Leg.—Fractures of the lower leg may be either isolated fractures of one bone or simultaneous fractures of both tibia and fibula. At the upper end of the leg the tibia may present fracture of the inner tuberosity, fracture of both tuberosities, very rarely fracture of the outer tuberosity alone, longitudinal fissures, separation of the upper tibial epiphysis and fracture of the tibial tubercle. Isolated fracture of the fibula just below the head is occasionally seen.

Fracture of the *inner tuberosity of the tibia* is closely analogous to fracture of the inner condyle of the femur, with which it articulates. (See Fig. 2521.) Its causation is very similar to that of fracture of the inner femoral condyle, and its symptomatology and diagnosis are elicited by similar maneuvers, that is to say there will be possible an abduction of the leg upon the thigh but not an adduction, local pressure over the tuberosity will give pain, and it will be possible to move the tuberosity independently of the shaft of the bone with crepitation. The treatment should be by fixation in nearly complete extension.

Fractures of *both tuberosities* are generally the result of a fall on the foot from a great height, the firm corticalis of the shaft acting as a wedge to split the two tuberosities asunder. The lesion is a very severe one and may demand primary amputation. Should this not be deemed necessary, the treatment should be by heavy and continuous traction with the leg extended. The severe attendant traumatic arthritis is apt to be followed by permanent ankylosis of the knee.

Fig. 2620.—Fracture of Both Tuberosities of the Tibia. (Stimson.)

Fracture of the *external tuberosity of the tibia* is rare, as this portion of the bone is largely protected by the femoral condyle and by the head of the fibula, and inasmuch as the external lateral ligament of the knee is inserted into the fibula and not into the external tuberosity of the tibia, the strains that might come to this portion of the tibia in forced adduction of the leg, are distributed elsewhere. Its treatment should be by fixation in extension.

The fractures of the *upper end of the tibia* are so largely the result of a direct thrust, substantially in the axis of the lower leg, that it is but natural to expect to find here a characteristic expression of the type of the fracturing force revealing itself in lines of fracture which are nearly parallel to the tibial axis. In no bone of the body are longitudinal fissures so often met as in the tibia, and these longitudinal fissures do not always induce a complete fracture of the bone, but show themselves as mere cracks in the cortical layer. This same tendency to a very slight obliquity of the line of fracture is seen also in the fractures already described of one, or of both tuberosities. When these fractures are incomplete, in the sense of not causing the separation of any portion of the bone, they are extremely difficult of diagnosis, but if they are not recognized, and are not treated with the prolonged fixation and abstention from weight bearing, which are proper for a true fracture of the bone, they lead to a most troublesome and obstinate chronic osteitis, which is apt to be accompanied by an equally obstinate arthritis of the knee. Local tenderness, ecchymosis without contusion, and a fortuitous discovery of the fissure from an advantageously placed *x*-ray plate, are the only means of fairly positive diagnosis.

Another form of partial fracture of the tibia is more common, and is less difficult of diagnosis; this is fracture of the tibial tubercle. In adults this is generally the result of direct violence, as a kick or a blow upon the tubercle, and takes the form of a complete separation of the tubercle from the shaft, which is not difficult of recognition, and is to be treated by suture or pegging. In children and adolescents the fracture is more often the result of indirect violence, and appears in the form of a partial separation of the lower tongue-like process of the epiphysis. The lesion has sometimes been called

Schlatter's disease. In neither the complete fracture of adults, nor the partial epiphyseolysis of children is the function of the quadriceps extensor completely abolished, for the reason that the insertion of the

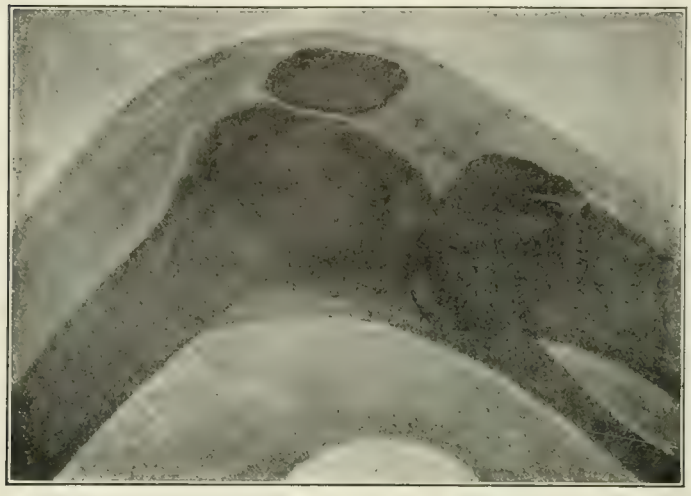


Fig. 2621.—Partial Separation of the Tongue-like Process of the Upper Tibial Epiphysis, Schlatter's disease. (Diagrammatic.)

patellar ligament into the tibia is by a broad aponeurotic expansion, which is rarely, if ever, completely torn across. Local tenderness and impaired extension, with instability of the leg, and a limping gait, are the symptoms of this fracture, though in the adult crepitation and independent mobility of the fragment can be readily made out. Operative fixation of the fragment, which is to be recommended in the adult, may sometimes be called for in children, but with sufficiently long-continued fixation of the knee in complete extension, most cases will get well, even if the limb continues in use.

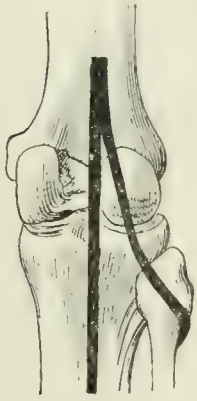


Fig. 2622.—Course of Peroneal Nerve around the Head of the Fibula. (After a sketch by Cotton.)

Fracture of the *upper end of the fibula* is important for two reasons, first because the fibular head bears the insertion of the external lateral ligament of the knee, and secondly, because of the course of the peroneal nerve which winds around the upper end of the bone, just below the head, in its passage from the popliteal space to the peroneal muscles and to the extensors of the toes. Foot-drop may follow injury to this nerve in fracture of the upper end of the fibula. Plaster-of-Paris encasement, with the knee in almost complete extension, is the indicated treatment.

One peculiarity has been noted concerning fractures of the upper end of the tibia, namely, that they demand, as a rule, a longer time for union than fractures of equal magnitude in other parts of the body. This is probably due to the fact that the main nutrient artery runs through a very oblique canal in the cortex, and is apt to be lacerated in these fractures, so that the process of bone repair is delayed until after the preliminary establishment of a collateral circulation in the bone.

Fractures of the *shaft of the leg bones* may or may not include both bones, and if both are fractured the fractures may or may not be at the same level, indeed there is a marked tendency for the fibular fracture to be situated higher up than that of the tibia. When the shaft of the tibia is broken it is often difficult to determine whether or not there is concomitant fracture of the fibula. In the absence of corroboration from the *x*-ray, we judge that the fibula also is fractured when the amount of displacement and of abnormal mobility is considerable, even when palpation does not clearly reveal a fibular fracture. The absolute determination of the presence or absence of a concomitant fibular fracture is not, however, a matter of great moment, as this bone bears but a very inconsiderable share in the office of weight bearing. Fractures of the shaft of the tibia, when nearly transverse, and especially if the fibula remains unfractured, are easy of determination, owing to the subcutaneous position of the bone, and they do not offer, as a rule, any special difficulties of treatment, which is most efficaciously provided for by a plaster-of-Paris bandage. Spiral and oblique fractures of the tibial shaft are, on the contrary, notoriously difficult to retain in proper position. The action of the powerful quadriceps extensor on the upper fragment, and that of the long calf muscles on the lower fragment, occasion a constant tendency to forward displacement of the lower end of the upper fragment, and to backward displacement of the lower fragment; and where the fibula likewise is broken, there is a most troublesome tendency to overriding. The lower end of the upper fragment causes one special type of difficulty, namely pressure on the overlying skin, which threatens to

Fig. 2623.—Fracture of the Shaft of the Tibia Showing Tendency to Displacement. (Internat. Textb. of Surgery.)

cause a necrosis with compounding of the fracture. In many cases the very greatest pains will not suffice to restrain this jutting forward of the sharp end of the upper fragment, in which case it is

Fig. 2624.—Mechanism of the Production of V-fracture of the Lower End of the Tibia. Pressure on the sole will cause the lower end of upper fragment to wedge the lower fragment apart into two lateral halves with wide diastasis and communication with the ankle joint. (Keen.)

good practice to make a clean incision over the protruding bone, and remove the offending tip with a chisel. It is rarely convenient, owing to the limited surface upon which the apparatus can hold, to apply permanent extension to the leg below the point of fracture, and the most approved treatment of these fractures, when spiral or oblique, is to keep the injured leg for ten days or more in a fracture-box or some other

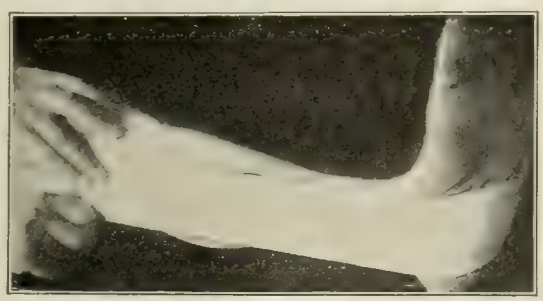


Fig. 2625.—Internal Artificial Ligament Applied with Strong Traction Bringing the Foot into Forced Adduction.

form of temporary dressing and after the primary inflammation and swelling have subsided, to apply a plaster-of-Paris bandage as in the less troublesome transverse fractures. In many cases, however, the application of a Lane's plate is for every reason advisable.

The *lower end of the tibia* is subject to fractures above the malleolus, which are generally, but not always associated with fracture of the fibula at about the same level. In this part of the bone there occur also fractures of a somewhat peculiar type, known as V-fractures, which are caused by a primary oblique fracture of the shaft becoming comminuted by the impaction of the lower end of the upper fragment into the lower fragment, whereby the lower fragment is split into two lateral halves. Epiphyseolysis of one or of both bones is occasionally seen, and the inner malleolus may be fractured without the concomitant fracture of the fibula and the subluxation of the ankle which would properly constitute a Pott's fracture.

All the fractures of the lower end of the shaft of the tibia are difficult of retention after reduction owing to the tug of the calf muscles upon the calcanear tuberosity, and in the comminuted fractures of this region the tendency to renewed displacement is extremely difficult to combat. Flexion of the knee, to relax these muscles, should therefore be a constant practice during reduction, and the flexed posture of the leg must be maintained, in many cases, during the period of consolidation of the bone. The least difficulty is encountered in epiphyseolysis, on account of the substantially transverse line of the separation, and the greatest difficulty in V-fractures, where direct fixation with bone-plates is often demanded. The principles of reduction and of treatment are substantially the same in fractures of the shaft higher up, but special attention must constantly be paid to the tendency of the calf muscles to draw the heel backward.

Isolated Fracture of the Lower End of the Fibula.—The lower end of the fibula, aside from the fibular lesion which is an essential element in a Pott's fracture, is subject to three types of fracture, a fracture through the shaft, a fracture of the external malleolus, and an epiphyseolysis.

It is wrong to confuse a simple isolated fracture of the shaft of the fibula in its lower third with a Pott's fracture, with which it has nothing in com-

Fig. 2626.—The Forced Adduction from the Internal Artificial Ligament is Being Corrected by Vigorous Traction on the External Artificial Ligament. The external artificial ligament as was the case with the internal was first applied near the knee so as to guide it true in passing around the foot; its upper end was then stripped off the leg as far as the sole to be reapplied with firm traction to bring the foot into the desired position.

mon but the break in the fibula, and whose grave consequences it does not share in any appreciable degree.

Isolated fractures of the lower end of the shaft of the fibula are sometimes very difficult of exact re-

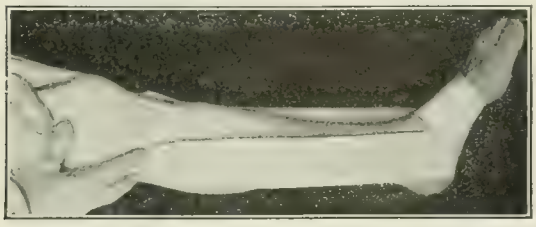


Fig. 2627.—Internal and External Artificial Ligaments in Position and Ready for Bandage.

duction, owing to the difficulty in obtaining a purchase on the bone by which it can be forced into proper line, but an imperfect reduction has but little effect upon the function of the ankle, and as the ankle-joint is not invaded, and the weight-bearing function belongs

Fig. 2628.—Man's Hunting Shoe and Lady's Lace Storm-shoe.

almost exclusively to the tibia, a degree of fixation which will prevent abduction and adduction of the foot, while allowing flexion and extension of the ankle, is all that is required. While a plaster cast is the usual method of treatment, a more convenient and, in most

Fig. 2629.—Typical Pott's Fracture. (Cotton.)

cases, a wholly adequate dressing is by means of a bilateral "artificial ligament" which is to be applied as follows. The leg having been shaved and asepticized from the knee down, a strip of adhesive plaster three inches wide is applied to the inner side of the leg, beginning a fingers-breadth below the head of the tibia, and is brought down the inner side of the leg so that the center of the strip shall pass over the inner malleolus; from thence, with the foot in full dorsal flexion, it is carried obliquely forward across the sole of the foot, to rise, on the outer side of the foot, across the fifth metatarsal, and is continued across the dorsum of the foot to its inner margin, where the strip is cut across. It is necessary to apply the strip first thus from above downward, in order to have the strip lie perfectly true to the parts, which is very difficult

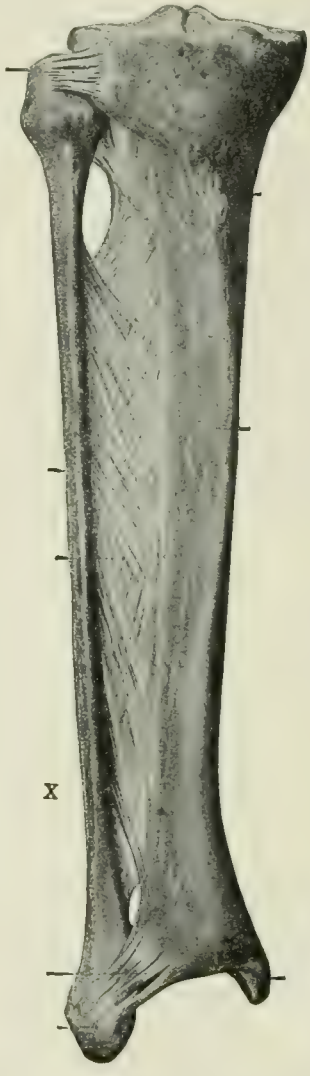


Fig. 2630.—The Interosseous Ligament Showing Anterior Fasciculi Running Downward and Inward. These are the only structures properly placed to resist abduction and upward thrust. The point x indicates the common site of the fibular lesion in Pott's fracture by abduction and eversion. (After Spalteholz.)

to accomplish when applied first from below. The lower end of the strip should now be applied closely to the skin, and the upper end should then be stripped from the leg, as far down as the sole of the foot, to be reapplied with a degree of traction sufficient to bring the foot into pronounced adduction, and the upper end of the strip should be held firmly against the leg by the patient or by an assistant. The external "artificial ligament" should reach from the head of the fibula, across the sole, up over the scaphoid and cunei-

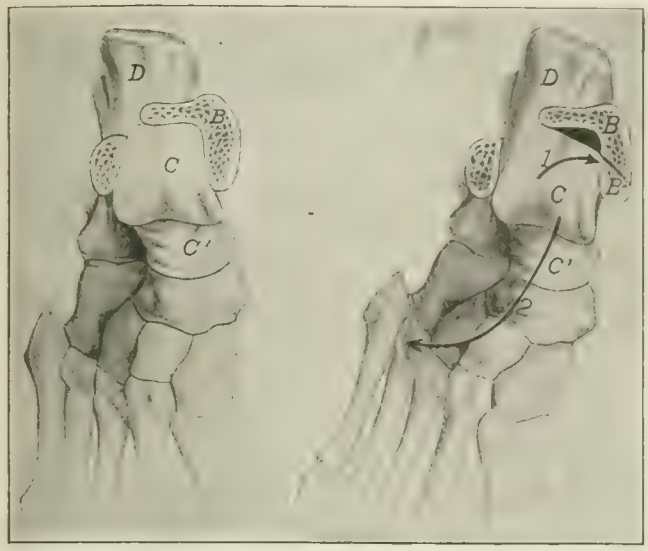


FIG. 2631.—Diagrammatic Drawing Representing the Effect of Forced Eversion in Producing Fracture of the Anterior Margin of the Inner Malleolus. This shows a section of the ankle joint at the level of the top of the astragalar trochlea. *A*, external malleolus. *B*, Internal malleolus and adjacent portion of the tibia. *B'*, the anterior portion of the same, forced off by the pressure of the everted foot. *C*, Trochlea of the astragalus. *C'*, neck of the astragalus. *D*, Tuberosity of the os calcis. The arrows 1 and 2 denote the direction of the force.

forms, to be cut off at the outer side of the dorsum of the foot. It should be applied first from above downward to secure an accurate and even hold on the parts,

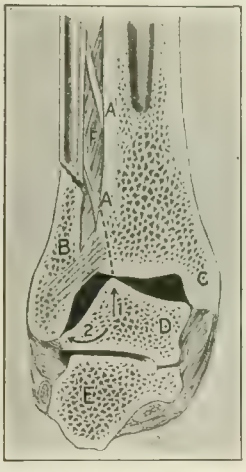


FIG. 2632. -Diagrammatic Drawing Representing the Effect of Forced Abduction in Producing Pott's Fracture. *A–A'*, the firm fibrous fasciculi of the anterior layer of the interosseous membrane acting in virtue of their direction downward and inward as stays to the shaft of the fibula which is broken obliquely across at the point of attachment of the lowest fasciculus through the force applied against the external malleolus, as indicated by the curved arrow (2). *B*, the lower end of the fibula. *C*, the internal malleolus. *D*, the astragalus so tipped in the ankle-mortise as to present a chisel-edge against the articular surface of the tibia and to split off a fragment when the weight of the body is imposed upon the heel. When a fragment is split off sufficiently long to carry off tibiofibular diastasis will result. *E*, the os calcis. *F*, the continuous posterior layer of the interosseous membrane, whose fibres, having a direction downward and outward are not fitted to withstand an upward strain through a fall on the abducted foot.

and after the lower end has been made secure, the upper end should be freed from the leg, and reapplied with sufficient traction to bring the ankle into a position midway between adduction and abduction; a certain excess of adduction may, however, be allowed to remain. The adhesive strips, particularly on the outer side, will stand away from the leg above the malleoli, but this will be corrected by the bandage, and its correction will serve to tauten the strips, which is desirable.

Over the plaster strips thus applied should now be adjusted a firm bandage of the foot, the ankle and the leg, and the foot will now be found to be fairly splinted, as far as regards adduction and abduction, but motions of flexion and of extension, as well as those of eversion (toeing out) and inversion (toeing in), while somewhat limited will still be possible.

Over the foot thus bandaged, the best form of boot to wear is a laced hunting boot, one or two sizes larger than the patient's regular foot wear. For ladies' use, a high laced golf shoe can be worn, and if the patient is careful of appearances, the purchase of two pairs of these shoes, one of the ordinary size, and the other two sizes larger, will allow the patient to go about with the two feet shod so nearly alike as to be very inconspicuous. Walking should be encouraged, and should, indeed, be insisted on, from the day the permanent dressing is applied, at first with a stick, never with crutches, and after as short a time as possible, with no other support than that afforded by the dressing.

This dressing with artificial ligaments is applicable also to isolated fracture of either malleolus, without luxation, which the *x*-ray has shown to be a not infrequent accompaniment of many sprains of the ankle. In isolated fracture of the inner malleolus a single internal artificial ligament will often suffice, by traction on which the foot can be held in slight adduction. In isolated fracture of the external malleolus, it is better to apply both an internal and an external artificial ligament, as putting the foot up in even slightly

FIG. 2633.—Fracture Lines through the Outer Portion of the Tibia. These fragments are not avulsed by traction of ligaments but are chiseled off by the upturned edge of the astragalus. (Bull.)

forced abduction is likely to lead to the development of a troublesome tendency to flat-foot.

The commonest injury to the region of the ankle, aside from a simple sprain, is the isolated fracture of the lower end of the fibula already described; isolated fractures of the malleoli are much more rare. A much severer injury of the ankle is, however, not uncommon and is properly known as a fracture-dislocation of the ankle-joint, but both convenience and usage have

fixed upon this lesion the name of Pott's fracture, after the English surgeon Percival Pott, who gave a lucid description of one form under which this lesion is seen, though the term Pott's fracture is used to-day to include all the fracture-dislocations of the ankle-joint, and not merely the fracture of eversion and abduction which Pott more specifically described.

Pott's Fracture.—Pott's fractures are broadly divided into two groups, based upon the luxation or the tendency to luxation of the foot. Much the commoner type is that produced by eversion and abduction, and the particular fracture described by Pott was of this variety. More seldom is the fracture by inversion and adduction, to which group the name of inverted Pott's fracture has been applied; these inverted Pott's fractures are apt to be more severe than are those of the first group. The typical Pott's fracture by eversion and abduction presents the following lesions of the bones. The fibula is obliquely fractured at a distance varying from one and a half to two and a half inches above the malleolus, and the obliquity of the line of fracture is with considerable constancy from below upward, and from the tibial side of the bone outward, indicating that it is caused by leverage exerted against the restraint of those fibers of the anterior layer of the interosseous ligament which run in a downward direction from their origin on the fibula to their insertion into the tibia. The tibial lesion is twofold, and presents first a partial fracture of the anterior lip of the inner malleolus, which is pried off by the trochlea of the astragalus, as this is twisted in its mortise by the forced eversion of the foot. The second tibial lesion is fairly constant, and consists in a splitting off from the outer (fibular) edge of the flat articulating surface of the tibia, of chips of bone, which are generally small, but may be so considerable as to carry upon them the tibial end of the anterior fasciculi of the interosseous ligament, above referred

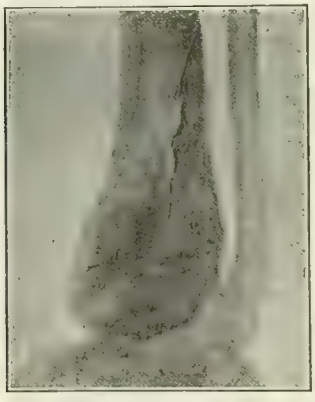


Fig. 2634.—Separation of Long Splinter from the Outer Side of Tibia, carrying away the lower anterior fibers of the interosseous ligament and permitting, under sufficient upward thrust with sufficient abduction of the foot, a wide tibiofibular diastasis. Characteristically the fibular lesion is minimal and is probably due to direct impact of the external malleolus against the side of the os calcis in forced abduction. The same forced abduction so rotates the astragalus in the mortise of the ankle joint as to allow the upper and outer edge of the trochlea to act as a blunt chisel to split off the large tibial fragment. In the illustration, which is a drawing from an *x*-ray taken from Cotton, the parts are no longer in the extreme abduction which must have been present when the fracture occurred.

to; in which case a fracture of the fibula by leverage against the restraint of these fibers does not occur, but is replaced by a wide diastasis of the fibula from the tibia, sufficiently marked in some cases to permit the astragalus to be forced up between the separated bones of the leg. These portions of the external side of the tibia, are not torn away from the bone by traction of the tibiofibular ligaments, but are, as it were, chiseled off from that bone by the upturned edge of the astragalar trochlea, when the weight of the body is imposed upon the strongly abducted foot.

In inverted Pott's fractures the fibular element consists generally in a clean shearing off of the whole of the external malleolus at its base, while the tibial fracture is never less than the whole of the internal malleolus, and generally includes a larger or smaller portion of

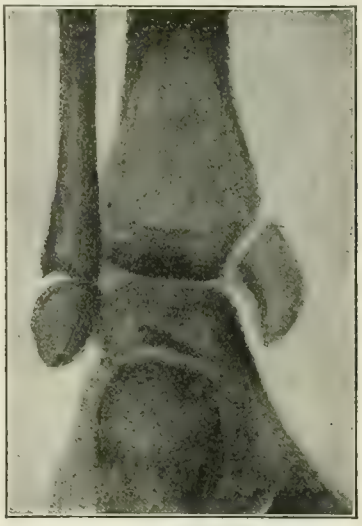


Fig. 2635.—Inverted Pott's Fracture, Showing the Action of the Edge of the Astragalar Trochlea in Chiseling off at Least the Whole of the Internal Malleolus. (Drawing from an *x*-ray plate by Scudder.)

the inner portion of the tibial shaft, and where the etiological elements of inversion and upward thrust, through the weight of the superimposed body, greatly predominate over the element of pure adduction, there is a tendency to a spiral or conchoidal fracture, which may carry away upon the curved, shell-like fragment a large portion of the tibial attachments of the ligaments binding the foot to the leg, so that extreme and troublesome luxation of the foot may follow, and may prove extremely difficult of retention after reduction.

Pott's fracture demands in most cases a temporary dressing of the injured foot in a fracture box, or in a pillow roll. The permanent dressing usually recommended is a plaster-of-Paris encasement. It is well, however, before applying the permanent plaster-of-Paris dressing to support and adjust the foot by means of the "artificial ligaments," described above as applicable to the treatment of isolated fracture of the lower end of the fibula, and to apply the plaster of Paris over the adhesive strips. Great pains must be taken in putting up a Pott's fracture in plaster of Paris to see that the foot is in full dorsal flexion, and in the commoner type of fracture by abduction and eversion, to see that the foot is held in slight overcorrection as regards the abduction, to obviate the troublesome tendency to traumatic flat-foot. In inverted Pott's fracture the artificial ligaments should be so adjusted as to hold the foot exactly midway between adduction and abduction.

Fractures of the Tarsal Bones.—Fracture of the astragalus is rare; it is generally the result of a fall from a height with the foot in full dorsal flexion so as to bring the full weight of the body, as transmitted through the tibia, onto the forward portion of the astragalar trochlea. The astragalus may also be

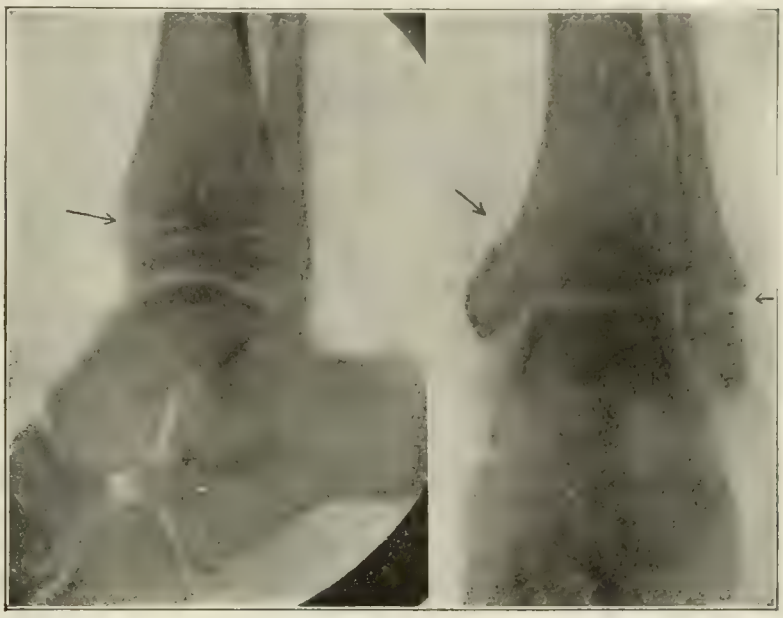


Fig. 2636.—Conchoidal Fracture of Lower End of Tibia in Inverted Pott's Fracture Carrying Away a Large Portion of the Ligamentary Insertions and Permitting Wide Dislocation of the Ankle, Generally Backward. (Scudder.)

fractured in backward dislocations of the foot, and its fracture is a rare but occasional complication of Pott's fracture. The treatment is by fixation of the foot and ankle in a plaster-of-Paris cast.

Fig. 2637.—Avulsion Fracture of Os Calcis. See Fig. 2535 for Crushing Fracture of Same Bone. Drawing from an *x*-ray plate by Scudder.

Fracture of the *os calcis* demands energetic measures to restore the obliterated arch of the foot, by bringing down the posterior fragment, which is invariably drawn upward by the inserted tendon of Achilles, as

Fig. 2638.—Cotton's Method of Bringing Down the Posterior Fragment in Difficult Cases of Fracture of the Os Calcis.

in default of proper replacement an incurable lameness will ensue. To this end it is of the highest importance to flex the leg at the knee, to relax the calf muscles, and to flex the foot and the toes as well by means of such an apparatus as is used in case of severing of the tendon Achillis. When the posterior fragment cannot be brought into proper position by imparting the proper attitude to the limb, Cotton recommends the passage of a convenient steel rod through the tissues anterior to the tendon, by means of which efficient traction can be exerted on the os calcis. In obstinate cases tenotomy may be resorted to. No weight bearing should be allowed under two months, under

Fig. 2639.—Proper Position for Treatment of Fracture of the Os Calcis.

penalty of seeing a recession of the posterior fragment and a permanent loss of the arch of the foot.

Fractures of the *remaining tarsal bones* and fractures of the *metatarsals* are almost always the result of crushing, and the fractures are very apt to be compound. In these cases the prophylactic use of the antitetanic serum is generally advisable and the treatment of the fracture, after the best possible

reposition has been secured by manipulation, should be by rest and abstention from weight bearing until such time as bony union shall have been secured, after which massage and graduated exercises will aid in the restoration of function. In some cases more complete rest can be secured by the use of a plaster cast. Similar treatment is appropriate to fractures of the phalanges. LEONARD W. BACON.

Frambœsia.—See *Yaws*.

Franco, Pierre.—Born at Turriers, in the Department of Basses-Alpes, France, about the year 1500. So far as can be learned, he was largely a self-taught physician; his success in the career of medicine being due chiefly to his love of knowledge and his own genius. After practising for a short time in the region in which he was born, he left France and settled in Switzerland—first at Fribourg, then at Lausanne and afterward at Berne. It is not known why he left his native country, but (according to Dezeimeris) the presumption is that the religious intolerance prevailing at that time made it dangerous for him to live in the south of France. That he had accepted the doctrines of the Reformation is rendered almost certain by the well-known fact that at that period a Roman Catholic would not have been permitted by the Swiss authorities to teach anatomy—one of the branches of medical knowledge which Franco taught in that country. Toward the end of his career—certainly before 1561—he returned to France.

Our knowledge of the work accomplished by Franco is derived exclusively from the remarkable book which he published in 1561. This book, which was republished in Paris under the title "La chirurgie de Pierre Franco", 1895, was distinguished from all other medical treatises of that period by the sound common sense which prevailed throughout every part of the work, by the fairness of his remarks upon the various operations which he described, and by the fact that almost everything which he had to say was based upon his own actual experience or upon observations which he himself had made.

A. H. B.

Frangula.—BUCKTHORN.—"The bark of *Rhamnus frangula* L. (fam. *Rhamnaceæ*), collected at least one year before being used" (U. S. P.). This is a very large shrub or small tree, growing throughout Europe and in adjacent Asia and Africa, and sparingly naturalized near New York City. The wood is very fine-grained, and its charcoal is largely utilized for powder-making, for which the bark must be first removed. The latter thus results as a by-product. It is largely employed in domestic veterinary practice, in the fresh or recently dried condition. It is then a sharply irritating cathartic or even emetic, but its griping properties are greatly mitigated by being kept. It occurs in strongly curved quills, which are commonly more or less flattened by pressure. The bark is very thin for the size of the quill (about one millimeter = $\frac{1}{25}$ inch). The outer surface presents two forms, the one nearly black, the other dark gray. Both are commonly marked by numerous transversely elongated white dots, and are somewhat warty-roughened, but never fissured or scaly. The inner surface, bright yellow when first collected, becomes successively dark yellow, brown, reddish, and nearly black with keeping, this being a fairly good way of recognizing its age. Its fracture is weak but not brittle, and is slightly fibrous. It has a slight characteristic odor and a bitter taste.

Composition.—With resin and a small amount of tannin, the important constituent of frangula is the yellow glucoside *frangulin*, or rhamnoxanthin ($C_{21}H_{20}O_8$) and its products *emodin* ($C_{15}H_{10}O_5$) and *isoemodin* ($C_{15}H_8O_4$). The development of all three of these substances proceeds as the dried bark ages, and coincidently the drug becomes a milder cathartic or laxative. Emodin and isoemodin belong to the class of *anthraquinones*, some one of which appears to give the properties to one large class of laxative drugs. Emodin, derived both from rhubarb and from frangula, is on the market. It is insoluble in water, little soluble in alcohol, but dissolves readily in alkaline solutions. It is not used medicinally in its own form.

Properties and Uses.—Frangula can be used as a cathartic in doses of ʒi.–ij.(4.0–8.0), but, like cascara sagrada, it acts much better as a laxative in doses of one-fourth or one-third these amounts. The fluid extract is official. Owing to its less mild and uniform action, frangula has almost entirely given way to cascara sagrada as a laxative.

The genus contains some seventy-five species, mostly in the north temperate zone, and gradually decreasing southward, in the mountains, a few in the south temperate zone. Many of them have a similar composition and action to that here described. *R. cathartica* L. has especially been so used, both the bark and the fruits (buckthorn berries) having been used as cathartics from ancient times. The bark of at least one species, *R. wightii*, of India, is a strong astringent. HENRY H. RUSBY.

Franzensbad.—A well-known mineral-spring resort of Bohemia, Austria, 142 miles by rail from Prague and twenty-nine hours distant from London.

The town itself is situated upon an elevated plateau, with a resident population of 2,540 and 15,000 annual visitors, most of whom are women; so that it has been called a "ladies' spa." Since 1793 Franzensbad has been visited by those seeking the curative effects of its waters, and it received its name from the Emperor Francis I.

The season extends from May to October, and the climate at this season is moderately cool, although rather hot in the middle of the day.

There is a fine park with pleasant promenades, and covered ways for rainy days. There are more or less attractive excursions in the vicinity. There is English Church service, a theater and the usual music common to all mineral spring resorts. The accommodations are abundant and good; the place is quiet.

There are fourteen different springs of a temperature of from 50° to 55° F., containing in varying quantities salines, alkalies, and iron with carbonic acid gas. The great specialty, however, of the place is the peat or mud baths, which are among the most noted in Europe. Gas baths are also given.

The most important springs are the Franzensquelle, Salzquelle, Stahlquelle, Kalter Sprudel, Wiesenquelle and Louisenquelle.

Sodium sulphate predominates in all the springs, and, in addition, there are carbonate of sodium, calcium, magnesium and iron, and chloride of sodium.

The principal springs are enclosed in elegant surroundings, especially the Franzensquelle.

Below is a comparison of the mineral ingredients of two of these springs with that of Carlsbad, also situated in this general region, taken from Yeo (The Therapeutics of Mineral Springs and Climates).

	Franzensbad, Salzquelle.	Carlsbad, Sprudel.	Franzensbad, Stahlquelle.
Sodium sulphate	2.802	2.405	1.614
Sodium carbonate	0.677	1.298	0.574
Sodium chloride	1.140	1.041	0.612
Calcium carb	0.183	0.321	0.199
Magnesium carb	0.103	0.166	0 053
Iron carb	0.009	0.003	0.078

The waters are used both internally and externally. As is the custom generally in spring resorts, the waters are taken internally at the springs in the early morning. The taste of the water is agreeable, though slightly ferruginous. For bathing the water is heated, and in the so-called "mineral" baths this is done by steam which drives off the gas, while in the "steel" baths the heating is done in such a way that the gas is retained.

For the peat or mud baths, the peat is obtained from the moorland in the surrounding district. It is dug up in the autumn and placed in heaps where chemical changes occur, forming a large number of sulphates, and the mass becomes jet-black, smooth, and homogeneous. Fresh peat is used for each bath, which is diluted with the mineral water, heated by steam, and given at a temperature of 90° to 95° F. The patient reclines in the bath, but so as not to allow the upper part of the chest to be covered. The peat is also applied locally for affections of the joints and limbs. The bath is said to be invigorating to the system and stimulating to the skin. After the mud bath one of clean water is taken.

The peat baths are recommended for anemia and chlorosis, chronic rheumatism, gout, scrofula and rickets; various nervous derangements, such as paralysis not of cerebral origin, the early stages of progressive muscular atrophy, and concussion of the spine; various sexual disturbances, as a tendency to abortion, prolapsus uteri, and loss of virility; and as an aid to the absorption of exudates and the infiltrations of intermuscular connective tissue, synovial sacs, ligamentous structures and glands.

The waters in general, as well as the peat baths, are considered especially valuable in the treatment of a great variety of sexual disorders in women; hence their popularity with this sex.

The following are some of the conditions treated here: Disorders of adolescence, and the period of sexual development, as amenorrhea, dysmenorrhea, leucorrhea. In older patients: chronic vaginouterine catarrh, chronic metritis, oophoritis, uterine displacements, pelvic inflammatory exudations, a tendency to miscarriage and repeated miscarriages, ovarian neuralgia, sterility, the exhaustion following profuse menstruation, the results of too rapid child bearing.

Other diseases treated are: chronic gastritis, hyperemia and moderate hypertrophy of the liver and spleen, gallstones, lithemia, habitual constipation, in obesity in the anemic, chronic gout, neurasthenia, anemia and scrofula.

Skin diseases which depend upon anemia and scrofula are also amenable to treatment by these waters. Such are: prurigo, urticaria, psoriasis, lichen, chronic eczema, and slow healing ulcers.

Gas baths are also administered to the entire body except the head, a chamber resembling the ordinary vapor-bath cabinet being used.

The waters of Franzensbad are also used as an after treatment to Carlsbad and Marienbad.

EDWARD O. OTIS.

Fraxinus.—ASH BARK.—The bark of various species of *Fraxinus* L. (fam. *Oleaceæ*). The commonly used species are the *F. excelsior* L. of Europe and the *F. Americana* L., or White Ash, of America, the inner root bark of which has been employed. The fluorescent glucoside *fraxin*, very common in the genus, seems to be less important therapeutically than the volatile oil and amaroid, which are present with a considerable amount of resin. Its composition would indicate its utility as a stimulant to nutrition. Its empirical use in the treatment of dysmenorrhea and metritis is, however, not explained. The dose is gr. xv. to lx. (1.0–4.0) and it is advised to be given in the form of a wine.

H. H. RUSBY.

Freckles.—See *Lentigo*.

Freer, Paul Casper.—Born in Chicago on March 27, 1862, he received his degree of M. D. from Rush Medical College in 1882. He then went to Germany where he passed five years chiefly in the study of chemistry, receiving the degree of Ph. D. from the University of Munich in 1887. Upon returning to America he was appointed instructor at Tufts College, Boston, and two years later was called to the chair of general chemistry and the directorship of the chemical laboratory at the University of Michigan. In 1901 he was appointed superintendent of the government laboratories, Manila, and member of the Philippine Islands Board of Health. In 1905 he was

FIG. 2640 Paul Casper Freer.

appointed director of the Bureau of Science in the Department of the Interior, and in 1907 dean of the College of Medicine and Surgery and professor of chemistry in the University of the Philippines. He established and was the first editor of the *Philippine Journal of Science*. He died April 17, 1912.

Dr. Freer was a scientist of unusual ability and an indefatigable worker, his published contributions numbering fifty-two and those written by pupils under his direct inspiration being as many again. He also wrote many reviews and editorial articles in the *Philippine Journal of Science*. His two most important works were "Descriptive Inorganic Chemistry," Boston, 1892, second edition 1895; and "The Elements of Chemistry," Boston, 1897. Doctor Freer was a member of numerous scientific societies:—American Chemical Society; Deutsche Chemische Gesellschaft; National Educational Association, of which he was President of the Scientific Section; American Association for the Advancement of Science, of which he was Secretary of the Chemical Section in 1897; Washington Academy of Science; Manila Medical Society; President of the Philippine Islands Medical Association, 1907; President of the first meeting of the Far Eastern Association of Tropical Medicine, in 1910.

T. L. S.

French Lick Springs.—Orange County, Indiana.

POST-OFFICE.—French Lick Springs. Hotels and boarding-houses. Access.—Via the Monon and Southern Railroads.

This is one of the old spring resorts of Indiana. The Indians made pilgrimages to these waters, for their beneficial qualities were widely known among them long before the white man penetrated so far into the West.

French Lick is situated in a beautiful valley in Southern Indiana. It is sixty miles from the center of population of the United States. The valley surrounded by lofty hills clothed with magnificent forests of maple, oak and beach, merges imperceptibly into

the picturesque parks, golf course and lawns in the immediate vicinity of the hotel. The altitude of French Lick is about 700 feet above the sea level, and its latitude is practically the same as that of Washington, D. C., Cincinnati and St. Louis.

The climate, although in many respects similar to that of these cities, nevertheless is greatly modified by topographical and various other local conditions. Generally speaking, the climate is soft and mild, and although not enervating it often exercises a peculiarly sedative influence upon nervous conditions.

The sanitary conditions are excellent. There are three mineral springs at French Lick, Pluto, Bowles, and Proserpine often called the "beauty spring."

The difference between the waters of these springs is qualitative rather than quantitative. They are perfectly clear, of a uniform temperature of 55° F. faintly effervescent, slightly bitter in taste, with a sulphurous odor. Although they contain practically the same salts, they differ both in taste and physiological action by reason of the varying proportions of their elements. They are commonly called sulphur waters but really belong to the sulpho-saline-alkaline class. Pluto water contains a predominance of sulphates,and is consequently the strongest laxative.

Bowles spring water containing largely carbonates and chlorides, is chiefly valuable as an antacid and diuretic.

Proserpine spring contains the largest quantity of sulphur, and it is the water of this spring that is used for the bath. All of these waters are artificially heated by being pumped through pipes surrounded by steam coils. In this way precipitation of the salts is prevented as is also the evaporation of the gases.

The following analyses of these springs were made by the Columbus Medical Laboratory of Chicago:

	Pluto.		Bowles.		Proserpine.	
	Parts per million.	Grains per Imperial gallon.	Parts per million.	Grains per Imperial gallon.	Parts per million.	Grains per. Imperial gallon.
Carbonic acid (total).	433.220		406 700		449.800	
Nitrogen	4.117		2.630		3.555	
Hydrogen sulphide	34.580		23.720		26.980	
Silica	24.400	1.708	12.000	.840	13.600	.952
Iron and alumina	Trace		1.000	.070	Trace	
Calcium oxide	703.600	49.352	593.000	41.510	679.600	47.572
Magnesium oxide	387.320	27.112	321.441	22.501	369.280	25.849
Sodium oxide	1,226.900	85.883	989.000	69.230	1,105.950	77.417
Chlorine	1,065.900	74.550	810.583	56.741	958.500	67.095
Carbonic acid	226.020	18.621	237.500	16.625	292.600	20.482
Suplhuric anhydride	1,631.000	114.170	1,421.000	99.470	1,573.000	110.110
The preceding ingredients are combined as follows:						
Silica	24.400	1.708	12.000		13.600	.952
Iron and alumina	Trace only		1.000	.070	Trace only	
Calcium sulphate	1,708.600	119.602	1,440.140	100.809	1,650.400	115.528
Magnesium sulphate	344.200	24 094	316.590	22.161	382.800	26.796
Sodium sulphate	680.000	47.600	644.500	45.115	615.950	43.116
Magnesium carbonate	558.620	39.103	453.400	31.738	507.600	35.532
Sodium chloride	1.995.000	139.650	1,518.410	106.288	1,795.500	125.685
Total.	5,310.820	371.757	4,386.040	306.181	4,965.850	347.609

The bath building immediatey adjoins the hotel. The building is fireproof and is heated and ventilated by indirect radiation. Among the features of this department are a Turkish or hot-air room; Russian, or vapor room, a pine-needle room, and special rooms for mud baths. There are also special rooms for the Nauheim, Aix, and Vichy baths. There is apparatus for all forms of douches and irrigations. And there is a graduated pool forty-five feet long for men and a smaller plunge for women.

The French Lick waters are used in the following conditions: Diseases of the stomach, liver, intestines, blood, heart and blood-vessels, urinary system, respiratory system, nervous system, female sexual organs, and skin; in appendicitis, autointoxication, rheumatism, diabetes, obesity, undernutrition; in diseases of nutrition and metabolism, and in intoxications. For those desiring these methods there are opportunities for the use of massage, electricity, gymnastics, and various other forms of indoor and outdoor exercise.

The French Lick Springs Hotel and the mineral springs are situated in grounds comprising 1200 acres lying between the station and the town. Although open throughout the year the most popular months are February, March, April, May, June, September, October and November.

The surrounding country is most picturesque. Fine roads reach out in all directions. The golf course immediately adjoins the hotel. In addition to golf, guests may enjoy tennis, baseball, trapshooting, horseback riding, driving, walking, motoring, bowling, and billiards. There are few days when fresh air exercise cannot be taken. The waters of French Lick Springs have an extensive commercial use.

EMMA E. WALKER.

von Frerichs, Friedrich Theodor.—Born in Friesland, March 24, 1819. In 1842 he began his career as a Doctor of Medicine, and advanced rapidly in his profession. In 1846 he delivered lectures at the University of Göttingen, and in 1850 went to Kiel, where he had been appointed Director of the Polyclinic and of the University Hospital. In 1857 he became Professor of Pathology and Therapeutics at the University of Breslau, where he was also Director of the Medical Clinic. In 1859 he was appointed Professor of Medicine at the University, and Director of the Medical Clinic at the Charité Hospital in Berlin. In 1884 the German Emperor conferred upon him the rank of Baron in honor of the twenty-fifth anniversary of his directorate of the First Medical Clinic in Berlin. His death occurred on March 14, 1885.

Frerichs attained renown as a physiologist, clinician, and teacher. The greater part of his life was devoted to instruction, for which he was by nature well fitted.

A man of attractive personality, quiet manner, but under all, one of strong passions. Among his most important contributions to medicine in writing are: "A Clinical Treatise on Diseases of the Liver," which

Fig. 2641.—Friedrich Theodor Frerichs.

received the Monthyon Prize of the Paris Institute, and was translated into various other languages, and published by the New Sydenham Society in 1861; a monograph on Bright's Disease, and one on Diabetes.

E. L. J.

Friedreich, Nikolaus.—Born in Würzburg, July 31, 1825, he received his education there and in Heidelberg, obtaining his medical degree from the Würzburg University in 1850. In 1853 he was appointed Privatdozent. During Virchow's stay at Würzburg, Friedreich was his student and assistant, and upon the former's transfer to Berlin in 1857, he succeeded to the chair of Pathological Anatomy. The following year he was appointed Professor of Pathology and Therapeutics and Director of the Medical Clinic at Heidelberg where he remained for the rest of his life. He died of aneurysm of the thoracic aorta on July 6, 1882.

Friedreich's name will ever be associated with hereditary ataxia which he described in an article entitled "Ueber Ataxie mit besonderer Berücksichtigung der hereditären Formen," in Virchow's *Archiv*, 1863. In the same volume was published an article on "Degenerative Atrophie der spinalen Hinterstränge," and in 1873 appeared his monograph entitled "Uebe Progressive Muskelatrophie, über wahre und falsche Muskelatrophie." He did not confine his studies to neurological subjects, however, being especially interested in the entire subject of diagnosis, on which he published numerous articles in medical periodicals. Other medical contributions of note were "Die Krankheiten der Nase, des Kehlkopfes, der Trachea, der Schild- und Thymusdrüse," published in Virchow's Handbuch in 1858, and "Die Krankheiten des Herzens," 1861.

T. L. S.

Friedreich's Ataxia.—See *Ataxia*.

Fructose.—Fructose or fruit sugar, as the name implies, is distributed with dextrose in various fruits, vegetables, and honey. From its action on polarized light it is called levulose since it has the power of turning the plane of polarized light to the left. When cane sugar is inverted dextrose and fructose are formed and the mixture is known as invert sugar. Like dextrose fructose may be directly utilized by the organism as a source of energy. In certain cases of diabetes mellitus levulose may appear in the urine. Fructose is readily soluble in water, but nearly insoluble in cold absolute alcohol, though rather readily soluble in boiling alcohol. The melting-point is 110° C. Levulose may be obtained very readily by the hydrolytic cleavage of inulin. Its formula is $C_6H_{12}O_6$ and it has the structure of a ketone, hence is known as ketose. See also *Aliment*.

F. P. Underhill.

Fry's Mineral Spring.—Jasper County, Iowa.

Post-office.—Colfax. Hotels and sanatorium.

This is one of a group of ten well-known mineral springs located at Colfax, on the line of the Chicago, Rock Island and Pacific Railroad, between Chicago and Omaha, twenty-three miles from Des Moines, with Interurban service hourly. Like all the others of the group, this spring has an artesian flow and proceeds from a depth of between 300 and 400 feet. The following analysis of the water from the Victoria Spring is taken from the Iowa Geological Survey, in the Annual Report for 1904, Volume XV.

One Imperial Gallon Contains

Solids.	Grains.
Sodium carbonate	3.76
Sodium sulphate	84.01
Potassium sulphate	0.54
Magnesium sulphate	26.68
Calcium sulphate	32.44
Calcium carbonate	99.63
Ferric carbonate	0.83
Silicon oxide	8.75
Lithia	Trace
CO_2*.	794.86
Total solids	255.64

*CO_2.—Weight of gas given off the water boiled. The water is classified in this report as a carbonated calcic saline chalybeate. Owing to the unusual quantity of sodium and magnesium sulphate held in solution this water is an excellent aperient. The alkalinity of the water also renders it useful in acidity of the stomach, and in many diseased conditions of the kidneys and bladder. On account of these properties together with "certain subtile qualities inherent in the constitution of the water, but evading analysis, this water has remarkable alterative qualities."

Although the water is quite strongly impregnated with mineral ingredients, it is not sufficiently so to mar its pleasant taste. Ample bathing facilities are provided. The elevation of the location is 1,100 feet above the sea-level, the surrounding country being of a hilly character. The waters of the spring have been found efficacious in rheumatism, the so-called uric-acid diathesis, constipation, catarrhal conditions of the stomach and bowels, obesity, dyspepsia, general debility, and in diseases of the blood, liver, kidneys, skin, glands, and nervous system. The modern sanatorium is well equipped.

Emma E. Walker.

Fulguration.—Fulguration (de Keating-Hart) consists in the application, to the area from which all macroscopic evidence of malignancy has been removed, of a monopolar current of high frequency, high tension, relatively low amperage, with a cooled long spark.

The premise upon which this method has been evolved is that this spark *acts not upon the neoplasm itself, but upon the soil on which the neoplasm has developed. The local trophism is thus modified in such ways that the tumor, being poorly nourished, tends to retrograde.* It will be seen at once that this method is in no wise to be confounded with "destructive fulguration," or high-frequency cauterization, in which the bipolar current, with a short spark, is utilized for "burning down" the growth.

Theoretical Basis of Fulguration.—When de Keating-Hart first began his experiments with the high-frequency current in the treatment of cancer he did not resort to excision of the neoplasm. He sought to produce, by means of the electric discharge, not an immediate and direct destruction of the tumor, as many thought, and as is attempted with "destructive

fulguration," but what he called its "sideration," a sort of stunning of the cancer cell. In consequence of this action the cell supposedly becomes partially devitalized, retrograding little by little, so that from

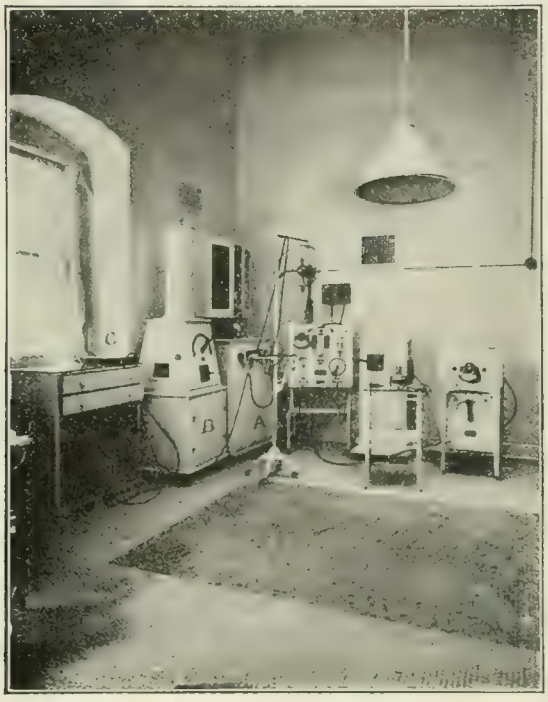


Fig. 2642.—Part of the Electrical Equipment, New York Skin and Cancer Hospital. *A*, Generating outfit containing coil, interrupter, etc.; *B*, high-frequency apparatus; *C*, cabinet containing electric sterilizer, with pump for forcing sterilized air through the rubber tube to the electrode.

a condition of anarchy there is a return to a condition of organized and orderly control.

When, however, de Keating-Hart came to realize the significance of his observation that cutaneous neoplastic nodules retrograde around a fulgurated region without themselves being touched by the discharge, he rejected the "sideration" hypothesis and accepted the idea that no notable modification, physiological, or histological, occurs in the tumor. He then sought to discover upon what tissues the current acts.

Observation and experiment led him to conclude that the soil or bed of the cancer is acted upon by the fulguration current, and that the tumor itself is in no way modified in its appearance or in its vitality. Facts and experiments confirmed the hypothesis, to the satisfaction of de Keating-Hart, that short sparks (from one to four centimeters long), at a relatively low tension, produce the effect of cellular stimulation, and provoke the rapid cicatrization of wounds. The high-tension spark, on the other hand, of a minimum length of eight centimeters, applied for a time sufficiently long in proportion to the surface fulgurated, retards cicatrization and transforms a given area into a torpid wound, which is closed, therefore, by a natural autoplasty instead of a cicatrization with the production of a large amount of scar tissue. The same trophic phenomenon that prevents the reformation of healthy epidermis after fulguration retards or suppresses the propagation (repullulation) of cancer *in situ*. The microscopic cancer cell, not the macroscopic growth, is attacked indirectly and destroyed by this method. According to corroborative experiments of Ghilarducci, the action of the current in fulguration manifests itself at a considerable distance from the point fulgurated, thus, presumably, tending to prevent metastasis.

Fulguration Apparatus.—Fig. 2642 shows the necessary apparatus for fulguration operations. This consists of: (A) a generating outfit, containing coil, interrupters, etc.; (B) high-frequency apparatus; (C) cabinet containing electric sterilizer for forcing cool sterilized air through rubber tubing to the electrode. Fig. 2643 shows various forms of the de Keating-Hart electrode. In addition to this equipment an operating table of wood or metal is necessary. When a wooden table is employed it must be grounded in order to prevent burning the patient.

The production of fulguration sparks may be accomplished by means of very differently adjusted apparatus. Static electricity and the city current may be utilized, according to circumstances. Dynamos or accumulators may be used.

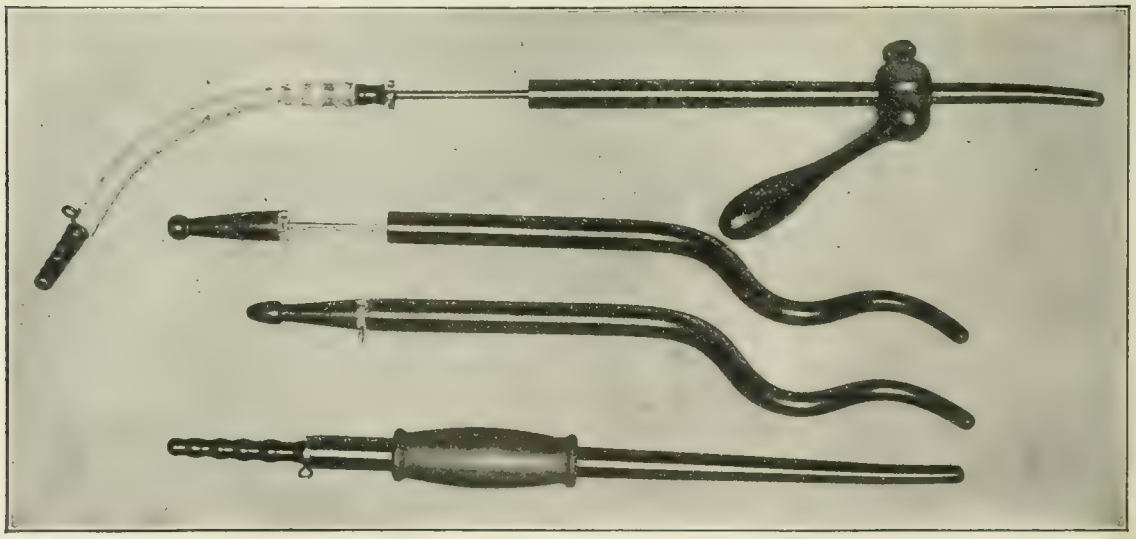


Fig. 2643.—Various Forms of de Keating-Hart Electrodes.

Surgical Technique.—In accordance with de Keating-Hart's present theory of the action of the current as applied in fulguration, the first step is always a surgical one. Fulguration is essentially a method of treatment for *operable* cancers. The more complete the removal of diseased tissue, the more certain, according to the theory, is the freedom from recurrence. The possibility of complete cure and absolute prevention of recurrence is commensurate with the extent to which eradication may be carried. Where only partial removal of diseased tissue is possible the method is palliative rather than curative. It may be said, in passing, that it has not yet been determined how much of the cure and prevention of recurrence is due to the thorough surgical removal and how much to the action of the electric spark upon the area from which the diseased tissue has been removed.

upon the basis of lack of uniformity of apparatus, variations in the primary current in the same apparatus, the distance of the spark-gap, and the conductibility of the air which surrounds it. The insulation of the patient is also a factor. Under such conditions the electrical properties of the spark are subject to enormous variation.

A general rule, however, may be given with reference to the duration of the application: Employ ten minutes of fulguration for an area of ten square centimeters. In the majority of cases and with the usual apparatus this is sufficient.

Another guide in the matter of duration is the change in the color of the tissues being fulgurated. All tissues assume a slightly darker tinge because of the deposit of small blood-clots produced at the surface through contact with the spark. This change of

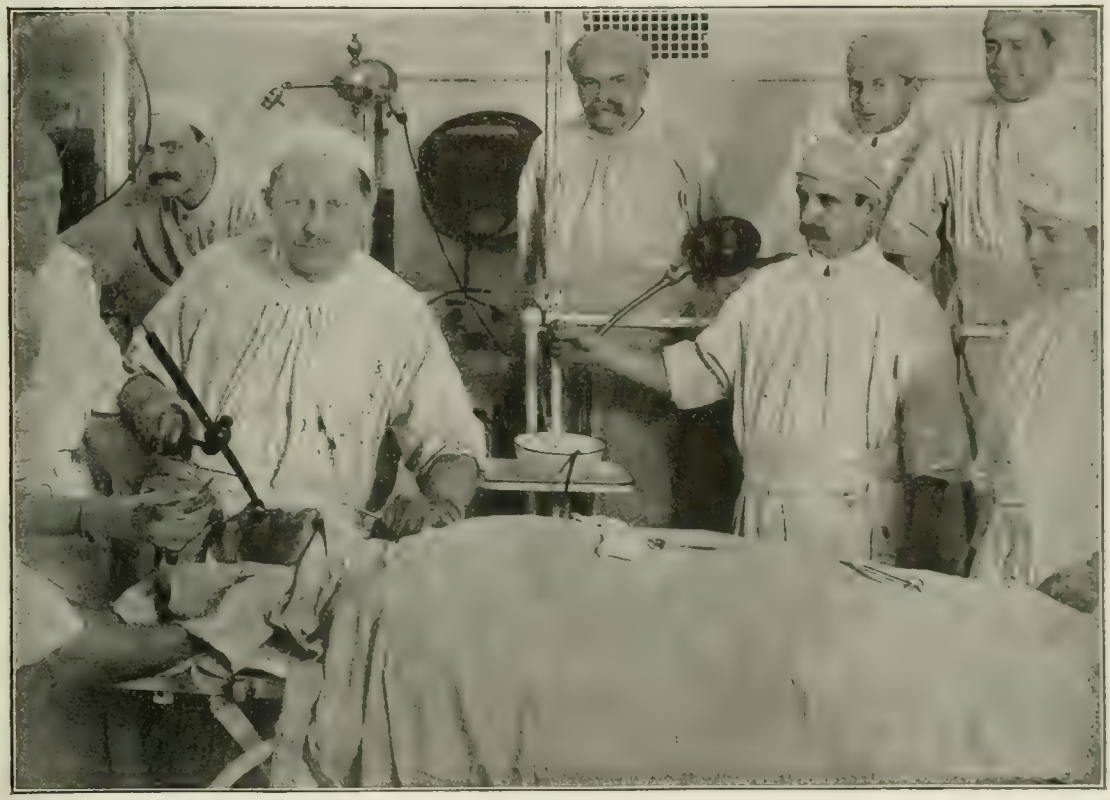


Fig. 2644.—Application of Spark to Area from which an Epithelioma of the Nose has been Removed, under Intravenous Anesthesia. Discoloration of the face is due to tincture of iodine.

Electrical Technique.—After every trace of macroscopic cancer has been removed, the sparks are applied to the surgical field. It is, then, under the cancer, and not upon it, that the electrical discharge is applied.

The spark should be white, and of a minimum length of from ten to twelve centimeters. Often we have used a maximum of from twenty to twenty-five centimeters. The electrode must be kept in constant motion, being passed regularly over the surface treated. The reason for keeping the electrode in constant, uniform motion, is twofold: (1) In order to prevent carbonization of the points at which the sparks strike the tissue; (2) in order to equalize the dosage, save at suspected points, where one must apply a larger dose.

The dosage or duration of the application of the spark upon a given point cannot be established in other than an empirical manner. This is explained

color varies with the tissues involved. The muscles take on a smoked-meat appearance and the bones become slightly more yellow. Too much dependence should not be placed upon this guide, however, as the degree of change depends upon the manner in which the sparking is carried out, and upon the thickness of the sanguinolent fluid through which it passes. Bones should not be fulgurated as long as muscles, or vessels as long as tendons.

Clinical Application.—de Keating-Hart claims that all kinds of cancer have given good results with fulguration. In very advanced cases, where cure is impossible, important palliative effects, such as the suppression of pain and hemorrhage, increase of strength, prolongation of life, have been noted by de Keating-Hart in seventy per cent. of cases treated by this method. He has reported 39.5 per cent. cures

in cancer of the breast; eighty-three per cent. cures or freedom from recurrence in cancers of the buccal mucosa for periods varying from seven and one-half months to two years; eighty-nine per cent. of success for a mean duration of sixteen months in inoperable sarcomas.

After thorough investigation upon several successive visits to Europe, this method of treatment seemed to the writer to offer possibilities for the prevention of recurrence, for amelioration, and possible cure of cancer. Whether the theory upon which it is based be right or wrong, many of the cases studied abroad seemed to indicate that fulguration exercises a favorable effect upon microscopic cancer not only in the immediate vicinity of but at a considerable distance from the original growth, thereby apparently preventing recurrence where it might logically be expected to occur.

Fig. 2645. Case I. Epithelioma of Scalp. Condition when operated upon March 11, 1912.

Apparatus, exactly duplicating that used abroad, was installed at the New York Skin and Cancer Hospital, where the method is being thoroughly tested. It has now been employed in 275 cases, with very encouraging results in a number. Careful records are being kept of all cases, and in time a final report will be published.

The following cases have been selected as fair illustrations of the successful application of the method:

Case 1.—*Epithelioma of scalp and glands of right side of neck.* (Figs. 2645 and 2646.) M. W. B. Female, aged twenty-two. Four years before consulting me a small ulcer appeared on the back of the head, in scar tissue which followed a burn when patient was one year old. Caustics were applied by the family physician, without effect. In May, 1911, the ulcerating mass was excised. The wound did not heal, but there was no extension until December, 1911, at which time she was sent by her physician to me.

Fig. 2646.—Case I. Condition July 6, 1912.

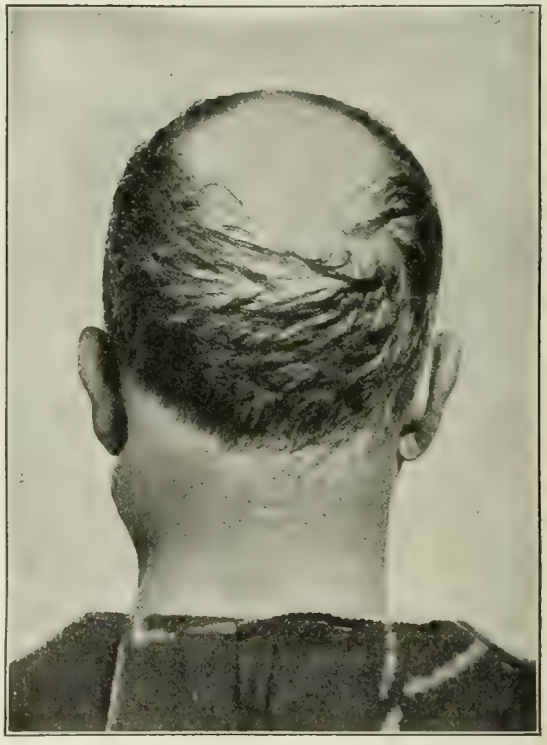


Fig. 2647.—Case II. Melanosarcoma of the Left Side of the Neck. Before operation and fulguration.

Fig. 2648.—Case II. Showing Incision Scar of Previous Operation.

Fig. 2649.—Case II. Condition after Operation and Fulguration.

Fig. 2650.—Case III. Epithelioma of the Nose. Condition when first seen.

Fig. 2651.—Case III. Condition after Operation and Fulguration. Ready for plastic surgery.

Operation, New York Skin and Cancer Hospital, March 11, 1912. Ulcerating mass excised, glands of neck removed, and both areas fulgurated. The fulgurated area on the head gradually became covered with epithelium, by natural autoplasty, without skin grafting. No recurrence, June, 1913.

Case 2.—*Melanosarcoma of left side of neck.* (Figs. 2647, 2648, and 2649.) O. L. Male, aged fifty-seven. Five months before treatment a small lump appeared on the left side of the neck. Variously treated, by different physicians, with external and internal agents. Tumor incised by one physician, diagnosis of melanosarcoma made, and Coley's fluid administered for several weeks without benefit. Admitted to New York Skin and Cancer Hospital, and operated May 13, 1912. A large mass was found adherent to internal jugular vein and carotid artery. This was carefully dissected out; internal jugular vein removed for three inches of its length and a long chain of melanotic glands removed from just above the dome of the pleura to the base of the skull. Wound fulgurated. Recovery uneventful. No recurrence and general condition excellent July 1, 1913.

Case 3.—*Epithelioma of nose.* (Figs. 2650, 2651, 2652, and 2653.) M. J. A. Female, aged seventy-seven. Twenty-five years ago, after striking her nose, a small red spot, size of finger nail, appeared.

Fig. 2652.—Case III. First Stage of Repair. Flap from forehead in place.

This was elevated, warty-like, and soon began to bleed. Treated by physician with salves and solutions, without benefit. It was finally excised and the bone curetted. No recurrence for five years. Recurrence then took place in the scar. Treated with local applications and *x*-rays, without benefit. Referred to me for operation. Operated, May 16, 1912. Growth removed down to cartilage of nose, and nose entered on left side. Wound fulgurated. Recovery uneventful. March 20, 1913, wound fulgurated again, April 3, 1913, plastic operation; flap brought down from forehead, with skin surface

Fig. 2653.—Case III. Condition after Completion of Plastic Operation.

turned in, leaving raw surface outward. Flap cut at its pedicle, April 24, 1913, and fitted into place and sutured. Raw surface covered by skin grafts. No recurrence July 1, 1913.

William Seaman Bainbridge.

Fumigation is a method sometimes employed in the administration of mercury for the treatment of syphilis. A mercurial salt such as calomel, is volatilized from a metal plate or a porcelain cup which is suspended over a spirit lamp. The whole apparatus is placed under a cane-seated chair, on which the patient, nude, is seated, and he si surrounded by a large blanket which is fastened about his neck. About thirty grains of calomel are used, and the process lasts for from fifteen to thirty minutes. This method is employed as an alternative to mercurial inunctions. Fumigations with sulphur have also been used in case of chronic skin diseases, such as scabies and eczema. R. J. E. Scott.

Fungi, Edible and Poisonous.—The treatment of this subject includes general remarks on edible and poisonous fungi, which should not be overlooked by the reader, followed by carefully drawn descriptions of species that may be eaten without much danger of making mistakes and other species that should be avoided because they are poisonous themselves or resemble poisonous species. The use of scientific descriptive terms is necessary for accuracy and brevity, and a brief glossary of them is appended. Classification is introduced only where it is necessary

to a proper understanding of the subject. The photographs used to illustrate the various species were made under my direction by Mr. F. C. Berte, and the colored plates by Miss M. E. Eaton and Mr. E. C. Volkert.

Edible Mushrooms.—The popular interest in mushrooms of all kinds is almost phenomenal. This is due to their beauty of form and color and the supposed mystery surrounding their origin and growth, as well as to the use of certain kinds for food. Their nutritive value is not great, being about equal to that of cabbage, but they afford variety in flavor and add greatly to the relish for other foods.

Mushroom eating is much more in vogue in Europe than in this country. The struggle for existence is greater there, and the edible and poisonous varieties are better known by all classes of people. In China, it is almost impossible for a botanist to get specimens on account of the thorough manner in which all wild food is collected by the natives.

The use of mushrooms in this country is as yet very limited, being confined chiefly to our foreign-born population. Even in New York City, many excellent kinds go to waste every season because they are different from kinds known in Europe. This is especially true of the puffballs, which do not seem to be generally recognized as edible. On the other hand, many species are collected in a wholesale and indiscriminate manner by ignorant foreigners, who, while searching the lawns for the common mushroom and the stumps for the beefsteak mushroom and the honey agaric, appear to gather everything they find at all resembling edible forms known to them.

All knowledge regarding the edible and poisonous properties of mushrooms is based on experiments, either intentional or unintentional. The only safe rule is to confine oneself to known edible forms until others are proven harmless. If one is a beginner, he is like an explorer in a new country with an abundance of attractive fruit near at hand, which may be good or may be rank poison; he cannot tell without trying it, unless some native, who has learned from his own and others' experience, shares his knowledge with him.

The writer on this subject undertakes a very responsible task, owing to the vast number of similar forms among the mushrooms which are distinguished with difficulty by those not accustomed to fine distinctions; but it should be possible to describe a few striking kinds in such a way that no serious mistakes will be made.

The common field mushroom is known to almost every one who pretends to collect mushrooms at all, and the majority of collectors limit themselves entirely to this one kind. It grows in low grass on meadows or on rich, moist upland pastures, being common after rains from August to October. The upper side is white with brownish fibrils or scales, and the under side is a beautiful salmon-pink when young, changing gradually to almost black when old. The stem is colored like the top and has a loose white ring around it. There is little or no swelling at the base of the stem and no "cup," as in the deadly amanita, which latter, moreover, is white underneath and grows usually in woods or groves.

The "spawn," or vegetative portion of the common mushroom, is hidden in the soil and feeds upon the dead organic matter found therein. When the proper season arrives, small fruit bodies, known as "buttons," appear on the spawn and soon develop into "mushrooms," which are in reality only the mature fruit bodies of a delicate and widely branching plant entirely concealed in the earth. The parts of the fruit body are popularly known as the "stem" and the "cap." On the under side of the cap are the "gills," which bear countless tiny bodies known as "spores," which are distributed by the wind and produce new plants as seeds do in the case of the flowering plants. The cottony "ring" on the stem is what remains of a thin white "veil" which covered the gills in the younger stages of growth. This veil is not present in all kinds of mushrooms.

In the cultivation of the common mushroom, bricks of spawn are planted in suitable soil and the conditions of growth attended to with great care. Any one wishing to grow mushrooms should provide himself with a good handbook on the subject, or learn the secret from a practical man in the business. It is not easy to do successfully unless done properly.

I have frequently noticed a tendency in young or inexperienced persons to belittle the dangers of mushroom eating, apparently believing that a show of bravado or fearlessness will overcome the effects of the poisonous kinds, as though they belonged to the category of myths or ghosts. It is, indeed, true that many varieties have been called poisonous when they were not, just as most of our snakes have been under the ban on account of the mischief done by three or four; but there are a few mushrooms that contain poisons just as deadly as that of the rattlesnake or copperhead, and these are responsible for practically all of the deaths due to mushroom eating. These poisons are narcotic rather than irritant, and their effects are slow to appear.

If distress is experienced within four or five hours after eating mushrooms, it is very probably a case of indigestion or minor poisoning and should readily yield to a prompt emetic. If, however, from eight to twelve hours have elapsed since eating the mushrooms, disagreeable symptoms should be taken very seriously, since it is almost certain that one of the deadly poisons is at work. A physician should at once be called and the heart action stimulated by a hypodermic injection of about one-sixtieth of a grain of atropine, which should be repeated twice at half-hour intervals. Atropine is an antidote to the poison of the "fly amanita," which paralyzes the nerves controlling the action of the heart. If the "deadly amanita" has been eaten, the atropine will probably do no good, and death will surely follow if the amount eaten is sufficient.

The deadly amanita, shown in two of its forms in Plate XXXV is a very conspicuous and beautiful object, occurring throughout the summer and autumn in open groves and along the edges of woods. Neither its odor nor its taste is disagreeable, as is the case with most inedible mushrooms, and it must be recognized by a careful study of its form and parts, which are, fortunately, very characteristic.

The most important part of the deadly amanita is the sheath at the base of the stem known as the "death-cup," which is well shown in the illustrations. This is what remains of the outer coat of the "egg" after the cap has burst from it and has been carried upward by the growing stem. The ring on the stem is similar to that of the common mushroom, but the gills are white, both when young and old, those of the common mushroom being at first pink, then black. Nothing can be told from the color of the upper surface of the cap because it varies so much, being pure white, yellowish, brownish, or blackish. Sometimes the surface is perfectly smooth and at other times it is adorned with pieces of the death-cup which were carried up on it when the cap burst through the roof of the egg.

When gathering mushrooms, it is exceedingly important to get all of the stem and not leave a portion of it in the ground, since the death-cup may thus be overlooked. Mushrooms should not be gathered in the "button" stage unless mature specimens are growing in the same place, otherwise an egg of one of the poisonous kinds may be collected by mistake.

The fly amanita is as beautiful as it is dangerous. The cap is usually bright scarlet, yellowish, or orange, sometimes fading to nearly white, and covered with conspicuous warts, which are portions of the death-

cup carried up from below. The rest of the cup will usually be found in fragments in the soil about the swollen base of the stem. The gills are white and remain so, thus differing from those of the common mushroom. The warts on the cap also distinguish it. I have not found this species common here, but it is very abundant in many localities, both in this country and in Europe.

The death-cup and its remains on the surface of the cap should always be looked for, and no mushroom of this group should be eaten by the beginner, although some of them are excellent.

My advice to beginners is to confine themselves at first to the common mushroom, the beefsteak mushroom, the puffballs, the coral mushrooms, and other readily recognizable forms, being careful to carry with them when collecting an accurate mental picture of the deadly kinds which have the death-cup or the peculiar patches on the cap, and to avoid mushrooms that are either too young or too old when selecting specimens for the table. If one must experiment, let him begin with experiments in cooking, since the way in which a mushroom is cooked often has much to do with its flavor and digestibility.

Mushrooms for Beginners.—Common Mushroom, Morel, Chantarelle, Beefsteak, and Sulphur-colored Polypore. Shaggy-mane, Common Inkcap, and Glistening Inkcap. All Puffballs, provided they are white, tender, and homogeneous within. All Coral-fungi, if they are fresh, crisp, tender, and have no bad odor nor bad taste. The Oyster Mushroom and its near relatives. These are large, with white gills and short stems, and grow on dead wood above ground.

Some Critical Edible Species.—Polypores that are sufficiently tender, avoiding certain Boleti and *Fomes Laricis*. Boleti that have been tested and found edible, avoiding *Suillellus luridus*, *Ceriomyces miniato-olivaceus*, and *Tylopilus felleus* in particular, or all species with red tube-mouths and bitter or peppery taste, and species that turn blue quickly when handled. Species of *Russula* and *Lactaria* with pleasant odor and flavor, avoiding such species as *L. rufa*, *L. torminosa*, *R. fœtens*, and *R. emetica*. Several species of *Lepiota*, avoiding *L. Morgani*, with green spores, and species of *Venenarius*. *Marasmius oreades* must not be confused with *M. urens*, nor with *Inocybe infida*. *Clitocybe*, *Tricholoma*, and *Collybia* are usually edible: avoid *Clitocybe illudens*. *Vaginata* too closely resembles *Venenarius*.

List of Edible Mushrooms.

Dr. Charles H. Peck, State Botanist of New York, has been studying fungi for fifty years. The following list comprises species definitely stated by him to be edible. His nomenclature is slightly different from mine in some groups.

Agaricus abruptus Pk.
Agaricus arvensis Schaeff.
Agaricus campester L.
Agaricus diminutivus Pk
Agaricus hæmorrhoidarius Schulz.
Agaricus micromegethus Pk.
Agaricus placomyces Pk.
Agaricus rodmani Pk.
Agaricus silvicola Pk.
Agaricus subrufescens Pk.
Amanita cæsarea Scop.
Amanita rubescens Fr.
Amanitopsis strangulata (Fr.) Roze
Amanitopsis vaginata Roze.
Armillaria mellea Vahl
Boletinus grisellus Pk.
Boletinus pictus Pk.
Boletus affinis Pk.
Boletus albidipes Pk.
Boletus albus Pk.
Boletus bicolor Pk.
Boletus brevipes Pk.
Boletus castaneus Bull.
Boletus chrysenteron albocarneus Pk.
Boletus clintonianus Pk.
Boletus edulis Bull.
Boletus edulis clavipes Pk.
Boletus eximius Pk.
Boletus frostii Russell
Boletus granulatus L.
Boletus laricinus Berk.
Boletus luteus L.
Boletus niveus Fr.
Boletus nobilis Pk.
Boletus ornatipes Pk.
Boletus pallidus Frost
Boletus rubropunctus Pk.
Boletus rugosiceps Pk.
Boletus scaber Fr.
Boletus spectabilis Pk.
Boletus subaureus Pk.
Boletus subglabripes Pk.
Boletus subluteus Pk.
Boletus versipellis Fr.
Bovista pila B. & C.
Bovista plumbea Pers.
Cantharellus aurantiacus (Wulf. Fr.
Cantharellus cibarius Fr.
Cantharellus cinnabarinus Schw.
Cantharellus dichotomus Pk.
Cantharellus floccosus Schw.
Cantharellus infundibuliformis (Scop.) Fr.
Cantharellus lutescens Fr.
Cantharellus minor Pk.
Clavaria botrytes Pers.
Clavaria botrytoides Pk.
Clavaria conjuncta Pk.
Clavaria cristata Pers.
Clavaria flava Schaeff.
Clavaria pistillaris L.
Clitocybe adirondackensis Pk.
Clitocybe amethystina (Bolt.) Pk.
Clitocybe clavipes (Pers.) Fr.
Clitocybe infundibuliformis Schaeff.
Clitocybe laccata Scop.
Clitocybe maculosa Pk.
Clitocybe media Pk.
Clitocybe monadelpha Morg.
Clitocybe multiformis Pk.
Clitocybe nebularis Batsch.
Clitocybe ochropurpurea Berk.
Clitocybe subcyathiformis Pk.
Clitopilus abortivus B. & C.
Clitopilus micropus Pk.
Clitopilus orcella Bull.
Clitopilus prunulus Scop.
Collybia acervata Fr.
Collybia dryophila (Bull.) Fr.
Collybia familia Pk.
Collybia platyphylla Fr.
Collybia radicata (Relh.) Fr.
Collybia velutipes (Curt.) Fr.
Coprinus atramentarius Fr.
Coprinus comatus Fr.
Coprinus micaceus Fr.
Cortinarius albidipes Pk.
Cortinarius cinnamomeus Fr.
Cortinarius collinitus Fr.
Cortinarius corrugatus Pk.
Cortinarius evernius Fr.
Cortinarius violaceus Fr.
Craterellus cantharellus (Schw.) Fr.
Craterellus cornucopioides Pers.
Crepidotus malachius B. & C.
Entoloma grayanum Pk.
Fistulina hepatica Fr.
Gyromitra esculenta Fr.
Helvella crispa Fr.
Hydnum albidum Pk.
Hydnum caput-ursi Fr.
Hydnum coralloides Scop.
Hydnum repandum L.
Hygrophorus cantharellus Schw.
Hygrophorus chlorophanus Fr.
Hygrophorus flavodiscus Frost.
Hygrophorus fuliginosus Frost.
Hygrophorus laricinus Pk.
Hygrophorus lauræ Morg.
Hygrophorus miniatus Fr.
Hygrophorus nitidus B. & C.
Hygrophorus pratensis Fr.
Hygrophorus pudorinus Fr.
Hygrophorus puniceus Fr.
Hygrophorus speciosus Pk.
Hygrophorus virgineus (Wulf.) Fr.
Hypholoma aggregatum sericeum Pk.
Hypholoma incertum Pk.
Hypholoma perplexum Pk.
Hypomyces lactifluorum (Schw.) Tul.
Lactarius camphoratus (Bull.) Fr.
Lactarius chelidonium Pk.
Lactarius deceptivus Pk.
Lactarius deliciosus Fr.
Lactarius distans Pk.
Lactarius gerardii Pk.
Lactarius lignyotus Fr.
Lactarius luteolus Pk.
Lactarius rimosellus Pk.
Lactarius serifluus (DC.) Fr.
Lactarius subdulcis (Bull.) Fr.
Lactarius subpurpureus Pk.
Lactarius volemus Fr.
Lepiota americana Pk.
Lepiota cepæstipes Sow.
Lepiota clypeolaria (Bull.) Fr.
Lepiota naucinoides Pk.
Lepiota procera Scop.
Lycoperdon atropurpureum Vitt.
Lycoperdon cyathiforme Bosc.
Lycoperdon gemmatum Batsch.
Lycoperdon giganteum Batsch.
Lycoperdon subincarnatum Pk.
Marasmius oreades Fr.
Mitrula vitellina irregularis Pk.
Morchella angusticeps Pk.
Morchella bispora Sor.
Morchella conica Pers.
Morchella deliciosa Fr.
Morchella esculenta Pers.
Morchella semilibera DC.
Paxillus involutus Fr.
Pholiota adiposa Fr.
Pholiota caperata Pers.
Pholiota discolor Pk.
Pholiota duroides Pk.
Pholiota præcox (Pers.) Fr.
Pholiota squarrosa Muell.
Pholiota squarrosoides Pk.
Pholiota vermiflua Pk.
Phylloporus rhodoxanthus (Schw.) Bres.
Pleurotus ostreatus Fr.
Pleurotus sapidus Kalchb.
Pleurotus ulmarius Bull.
Pluteus cervinus (Schaeff.) Fr.
Polyporus sulphureus Fr.
Psilocybe fœnisecii (Pers.) Fr.
Psilocybe polycephala(Paul.)Pk
Russula abietina Pk.
Russula albida Pk.
Russula brevipes Pk.
Russula compacta Frost.
Russula crustosa Pk.
Russula earlei Pk.
Russula flavida Frost.
Russula furcata (Pers.) Fr.
Russula mariæ Pk.
Russula nigricans (Bull.) Fr.
Russula ochrophylla Pk.
Russula pectinatoides Pk.
Russula pusilla Pk.
Russula roseipes (Secr.) Bres.
Russula rugulosa Pk.
Russula sordida Pk.
Russula subsordida Pk.
Russula uncialis Pk.
Russula variata Banning
Russula virescens Fr.
Russula viridella Pk.
Strobilomyces strobilaceus (Scop.) Berk.
Stropharia bilamellata Pk.
Tricholoma hirtellum Pk.
Tricholoma imbricatum Fr.
Tricholoma nudum (Bull.) Fr.
Tricholoma personatum Fr.
Tricholoma portentosum centrale Pk.
Tricholoma radicatum Pk.
Tricholoma russula (Schaeff.) Fr.
Tricholoma silvaticum Pk.
Tricholoma sordidum (Schum.) Fr.
Tricholoma subacutum Pk.
Tricholoma subsejunctum Pk.
Tricholoma terreum fragrans Pk.
Tricholoma transmutans Pk.
Tricholoma unifactum Pk.
Volvaria bombycina (Pers.) Fr.

EXPLANATION OF PLATE XXXIV.

EXPLANATION OF PLATE XXXIV.

SOME EDIBLE MUSHROOMS.

Fig. 1.—Agaricus campester

Fig. 2.—Rostkovites granulatus

Fig. 3.—Russula mariæ

Fig. 4.—Chanterel chantarellus

Fig. 5.—Ceriomyces crassus

Fig. 6.—Melanoleuca personata

Fig. 7.—Coprinus micaceus

Fig. 8.—Marasmius oreades

Fig. 9.—Ceriomyces crassus separans

Fig. 10.—Lactaria lactiflua

Fig. 11.—Hypholoma perplexum

Fig. 12.—Hypholoma appendiculatum

Fig. 13.—Armillaria mellea

SOME EDIBLE MUSHROOMS (MURRILL)

Poisonous Mushrooms.—Considering its importance, it is remarkable how little is really known about the subject of poisonous mushrooms; and the statements and opinions of various authors are so conflicting that one often does not know what to believe regarding the commonest and best known forms. Most of the literature centers about two species, *Venenarius muscarius* and *Venenarius phalloides*, which, owing to their abundance, wide distribution, conspicuous appearance, and deadly qualities, have been the chief causes of death from mushroom eating the world over. The clinical side of the subject is an old one, but careful chemical investigation into the causes of the effects observed dates back only about two decades, being dependent upon the development of modern methods in organic chemistry.

As the use of mushrooms in this country for food becomes more general, the practical importance of this subject will be vastly increased and it may be possible to discover perfect antidotes or methods of treatment which will largely overcome the effects of deadly species. This would be a great boon even at the present time, and there will always be children and ignorant persons to rescue from the results of their mistakes. Another very interesting field, both theoretical and practical in its scope, is the use of these poisons in minute quantities as medicines, as has been done with so many of the substances extracted from poisonous species of flowering plants, and even from rattlesnakes and other animals. Thus far, only one of them, the alkaloid muscarine, has been so used.

The poisons found in flowering plants belong chiefly to two classes of substances, known as alkaloids and glucosides. The former are rather stable and well-known bases, such as aconitine from aconite, atropine from belladonna, nicotine from tobacco, and morphine from the poppy plant. Glucosides, on the other hand, are sugar derivatives of complex, unstable, and often unknown composition, such as the active poisons in digitalis, hellebore, wistaria, and several other plants.

The more important poisons of mushrooms also belong to two similar classes, one represented by the alkaloid muscarine, so evident in *Venenarius muscarius*, and the other by the deadly principle in *Venenarius phalloides*, which is known mainly through its effects. Besides these, there are various minor poisons usually manifesting themselves to the taste or smell, that cause local irritation and more or less derangement of the system, depending upon the health and peculiarities of the individual.

The history of mushroom poisoning reaches back to Babylonia and ancient Rome, and every year since then has added to the list of victims, many of whom have been persons of importance. In some cases, poisonous species were used in committing murder. The annual number of deaths in the United States due to mistaking poisonous species for edible ones is probably fifty or more, many of which are not reported.

The characters and tests used to distinguish poisonous mushrooms have been most varied and curious, and nearly always mixed with queer traditions and superstitions. If the percentage of deadly forms were not so small, probably not over one per cent., the fatalities from this source would have undoubtedly been much more numerous. The only safe rule to follow is the one used with other plants, namely, to know each species accurately before eating it. Even the rules carefully formulated by mycologists are almost certain to prove unreliable as men grow bolder and attempt to eat species not previously tested, because everything that is known in this field has been discovered by experiment, and predictions or generalizations of any kind are both unscientific and unsafe. It may be possible to forecast accurately the discovery of a new chemical element with given properties, but mushrooms have not yet been reduced to that basis.

The Chief Poisonous Species.—*Venenarius phalloides*, *V. muscarius*, *V. pantherinus*, *V. cothurnatus*, and *V. solitarius*. *Clitocybe illudens*. *Inocybe infida*. *Panus stypticus*. *Chlorophyllum molybdites*. *Russula* and *Lactaria*, about ten species. Rosy-spored species, a few. Several of the phalloids, probably. Several species not yet tested, doubtless. Note that no brown-spored, purplish-brown-spored, nor black-spored species are listed above, but not all have been tested.

Preparing and Cooking Mushrooms.—Reject old specimens or those infected with insects, cut off the stems except in rare cases when they are unusually tender, peel a few kinds that seem to require it, wash quickly in cold water, drain and keep in a cool place until ready to cook. As a rule, mushrooms cannot be kept very long in a fresh condition, and this is particularly true of certain very desirable species. When more are collected than can be used at once, it is best to boil them ten minutes, drain, keep in a cool place, and finish the cooking next day as desired. If allowed to stand in water, the flavor is impaired; also, peeling may remove some of the best flavored parts.

The flavor and digestibility of mushrooms depend very largely on the way they are cooked. Tender varieties should be cooked quickly and served at once; tough varieties require long, slow cooking. When the flavor is good, it should be retained by covering during the cooking process and seasoning in a simple way. When the flavor is poor or when the specimens are slightly bitter or otherwise objectionable in the raw state, they may often be greatly improved by boiling for a short time and throwing the water away, then cooking thoroughly and seasoning well. It is often desirable to mix a few highly flavored specimens with those lacking flavor. Mushrooms are also excellent cooked with meat, poultry, oysters, tomatoes, or sweet peppers, and as a flavoring for soups and sauces.

Detailed directions for cooking mushrooms are given in most of the books. The most practical and successful methods resolve themselves into broiling, baking, and stewing. In the first, which I prefer to all other methods, the mushrooms are cooked thoroughly but as quickly as possible, on both sides over a hot fire; seasoned with pepper, salt, butter, and perhaps small bits of toasted bacon; and served hot on toast. To bake mushrooms, line the pan with toast, add the specimens, season, pour in half a cup of cream, cover closely, and bake rather slowly for fifteen minutes or more according to quality. In stewing, the mushrooms are boiled in water until thoroughly cooked, then seasoned, thickened, and served on toast. This last method is often used for the tougher or poorer varieties. Certain modifications of the above methods may be suggested later under individual species requiring special treatment.

Descriptions of Edible and Poisonous Mushrooms.

No reliable general rules can be given for distinguishing edible and poisonous species of fungi; each must be known by its own specific characters. In addition to the scientific descriptions, many illustrations and descriptive notes are added. The order of treatment follows the lines of classification adopted by the best authorities. It is impossible to use keys in an incomplete list of this kind without being misleading; keys are possible only when all the known species of a group or of a region are included. Technical terms are defined in a brief glossary at the end of this article.

Morchella esculenta Pers. Edible. *Common Morel*, *Esculent Morel*. (Fig. 2654.)—Pileus ovoid, three to six centimeters long and two to four centimeters thick, yellowish-brown, becoming darker with age, marked over its entire surface with broad pits separated by

ridges forming a network; stipe white, granular, about as long as the pileus, but only half as thick.

All of the morels are edible, very similar in appearance, and readily recognized, so that it is unnecessary to describe other species. They occur in thin woods, especially pines, in May and June. On account of their pitted surface, they must be cleansed very thoroughly, and because of their toughness and lack of flavor they must be cooked slowly a long time and well seasoned. Place them in a stewpan with butter, salt, pepper, and a little lemon juice, and cook slowly for an hour, adding at times a little beef gravy. The only poisonous species that might be confused with the morels is *Gyromitra esculenta*, known by its dark red, irregular cap, which is not pitted, but folded and convoluted somewhat like the surface of the human brain; however, it occurs at the same time as

Fig. 2654.—Morchella esculenta.

the morels and assumes brownish hues with age. Although young and fresh specimens of *G. esculenta* are regularly eaten without harm, old or decaying specimens or those kept too long before cooking have at times been found to contain helvellic acid, a deadly poison similar to that occurring in *Venenarius phalloides*, and it is therefore wise to refrain from using the plant for food in any form.

Hymenomycetes.—Fungi belonging to this large group produce their spores on thin membranes spread over the surfaces of gill-like structures or tubes or spines, or, in some cases, over the smooth surface of the hymenophore. The chief families are: (1) Tremellaceæ, sporophore irregularly expanded, gelatinous; (2) Thelephoraceæ, spore-bearing surface even, pileus present; (3) Clavariaceæ, spore-bearing surface even, sporophore club-shaped or bush-like and fleshy; (4) Hydnaceæ, bearing spines; (5) Polyporaceæ, tough or woody and tube-bearing; (6) Boletaceæ, fleshy and tube-bearing; (7) Agaricaceæ, bearing lamellæ. The last two families are by far the most important for our present purpose.

Clavariaceæ.—The coral mushrooms are easily known by their striking resemblance to clusters of delicately branched coral. They grow on the ground or on rotten wood in dense shade, and are whitish or yellowish in color. Unfortunately, I have not found them abundant about New York. When tender and of mild flavor, they make a delicious dish. None of them are known to be poisonous, although some are insipid or bitter. A very common white species of *Lachnocladium*, resembling *Clavaria*, will readily be recognized as much too tough for the human stomach. Coral mushrooms may be cooked as other mushrooms are, or escalloped, or stewed slowly for half an hour with the usual seasoning and a little lemon juice, then thickened and cooked longer until tender.

Clavaria flava Schæff. Edible. *Pale yellow Clavaria.* (Fig. 2655.)—Sporophore bushy, seven to fifteen centimeters high, five to ten centimeters wide; base thick, fleshy, white, dividing abruptly into a dense mass of erect, pale yellow branches, the tips more deeply colored but fading with age; context white, mild, of good flavor.

Fig. 2655.—Clavaria flava.

This excellent, as well as beautiful, species occurs rather abundantly in woods during warm, wet weather. In collecting it, the base should be examined for insects, which might give a disagreeable flavor to the whole plant. The golden Clavaria, *C. aurea*, is similar, but more deeply colored. The rarer red-tipped Clavaria, *C. botrytes*, has red-tipped branches, the color of which fades out with age. There is an unbranched, club-shaped species, *Clavaria pistillaris*, which is also often eaten.

Hydnaceæ.—In this family, the spores are borne on the surface of spines. No poisonous species are known, but most of them are too tough or too poorly flavored to be recommended for food. *Fistulina* belongs to a related family which need not be discussed here.

Hydnum repandum L. Edible. *Spreading Hydnum.*—Pileus convex to plane, irregular, very brittle, varying greatly in size, two to sixteen centimeters broad; surface dry, glabrous, smooth, white to buff or brown, margin wavy; context white or whitish, tender; spines white or yellowish, straight, very brittle; stipe eccentric, usually clavate, concolorous or paler, two to ten centimeters long, one to two centimeters thick.

This species is widely distributed, occurring during late summer among moss or leaves in woods. It is too tender to require long cooking, but most directions call for an hour or more. If sliced and steeped for twenty minutes in warm water before cooking, the

flavor seems to be improved. Some of the species of this genus that are bitter may be used if boiled for a short time in water before cooking. *Hydnum imbricatum* differs from *H. repandum* in being blackish-brown as though scorched and conspicuously scaly, with bluish-gray teeth. Although rather tough and dry, it is frequently eaten.

Fig. 2656.—Hydnum caput-ursi; young stage.

Hydnum caput-ursi Fries. Edible. *Bear's Head Hydnum.* (Figs. 2656 and 2657.)—Large, fleshy, tuberculiform, immarginate, pendulous, rarely erect, white, seven to fifteen centimeters or more thick, the surface everywhere emitting short branches, which are clothed with branchlets and awl-shaped, deflexed spines one to twelve centimeters long; context firm, white, somewhat tough, of mild flavor; spores globose, hyaline, 5–6μ.

This striking species occurs in temperate regions during summer and autumn on dead or dying trunks of deciduous trees, especially beech and birch. While somewhat tough, it can be made very attractive by

Fig. 2657.—Hydnum caput-ursi; fully grown.

proper cooking. *Hydnum coralloides*, resembling a mass of white coral, is a closely related species found chiefly on dead beech trunks. It is more tender and has an excellent flavor.

Fistulina hepatica (Huds.) Fries. Edible. *Beefsteak Fungus. Vegetable Beefsteak. Oak Tongue. Chestnut Tongue. Beef Tongue.*—Pileus large, fleshy, very juicy, dimidiate to flabelliform, five to fifteen centimeters broad; surface dark red, somewhat sticky when moist, radiate-striate with age, margin entire to lobed; context thick, soft, tough, streaked with dark and light reddish lines, acid to the taste; tubes at first short, yellowish or pinkish, becoming three millimeters long, plainly distinct from one another, and dull ochraceous with age; spores ellipsoid, smooth, yellowish, 5–7μ long; stipe usually short and thick, lateral, colored like the pileus, often reduced to a mere tubercle and sometimes wanting.

This species occurs on decaying trunks and stumps of chestnut, oak, and certain other deciduous trees in this country and in Europe. On account of its resemblance to a piece of beefsteak, it has long been recognized and used for food. It should be thoroughly cooked, and, if the acid flavor is objectionable, sodium carbonate should be added during the process of cooking. I have found this fungus much more common on chestnut than on oak, and I have noticed that foreigners regularly visit old chestnut stumps and trunks in the vicinity of New York during late summer and autumn to obtain it. Since the chestnut trees have all been killed by the canker, the beefsteak fungus should appear in great quantity.

Polyporaceæ.—Most of the species of this group grow on dead wood in brackets of various sizes and shapes, the fruiting surface being composed of tubes or furrows. When the fruit-body is perennial, the tubes are often arranged in layers. Polypores as a class are very destructive to trees and timber. On the other hand, one species possesses medicinal properties, some of the encrusted species supply tinder, and several of the more juicy ones are excellent for food if collected when young. The only species recognized as poisonous is the medicinal one, *Fomes laricis*, usually known as *Polyporus officinalis*, and it is so tough and bitter that no one would think of eating it.

Grifola frondosa (Dicks.) S. F. Gray. Edible. *Polyporus frondosus* (Dicks.) Fries, *Frondose Polypore.* (Fig. 2658.)—Pileus imbricate-multiplex, fifteen to forty centimeters in diameter; pileoli very numerous, branching from a common trunk, imbricate or confluent, variable in size and shape, dimidiate to flabelliform, one and one-half to six centimeters broad; surface smoky-gray, fibrillose, radiate-striate; margin very thin, tough, fragile, having the odor of mice; tubes white, two to three millimeters long, mouths circular and regular when young, three to a millimeter, often large and angular with age, edges white, thin, entire to lacerate; spores subglobose to ellipsoid, smooth, hyaline; stipe tubercular, white, connate-rimose.

This large, branched species grows commonly in Europe and North America at the base of oak trees or arises from their roots, on which it feeds. It also attacks the roots of chestnut trees, and in the Italian chestnut orchards it is often allowed to destroy the host because it is much esteemed in that region for food. It must be eaten when young or it will become too tough. It is best broiled with butter for about twenty minutes, or it may be stewed for nearly an hour.

Lætiporus speciosus (Batt.) Murrill. Edible. *Polyporus sulphureus* Fries, *Sulphur-colored Polypore.*—Hymenophore cespitose-multiplex, thirty to sixty centimeters broad; pileus cheesy, not becoming rigid, reniform, very broad, more or less stipitate, 5–15$\times$7–20$\times$0.5–1 centimeter; surface finely tomentose to glabrous, rugose, anoderm, subzonate at times, varying from lemon-yellow to orange, fading out with age; margin thin, fertile, concolorous, subzonate, finely tomentose, undulate, rarely lobed; context cheesy, very fragile when dry, yellow when fresh, usually white in dried specimens, homogeneous,

three to seven millimeters thick; tubes annual, two to three millimeters long, sulphur-yellow within, mouths minute, angular, somewhat irregular, three to four to a millimeter, edges very thin, lacerate, sulphur-yellow, with color fairly permanent in dried specimens; spores ovoid, smooth, or finely papillate, hyaline, 6–8×3–5μ.

This very large and widely distributed species appears in conspicuous clusters on dead spots in the trunks of various kinds of trees, which are seriously attacked by it. It has long been used for food and can hardly be confused with harmful species. I have found it best broiled, when it reminds one of salmon.

Fig. 2658.—Grifola frondosa.

Boletaceæ.—Many of the best edible fungi in temperate regions belong to this group, and the dangers of being poisoned are relatively small. Species with bitter or otherwise objectionable taste should be avoided, and especially all plants having red or reddish tube-mouths. The sensitive bolete, which promptly turns blue when touched or broken, has also caused mild poisoning in some cases. Many species have not been thoroughly tested, however; hence it is wise to eat sparingly of all such plants until well known.

Tylopilus felleus (Bull.) P. Karst. Inedible. *Boletus felleus* Bull., *Bitter Boletus.*—Pileus thick, convex, usually eight to fifteen centimeters broad, sometimes reaching a diameter of over forty centimeters; surface smooth, glabrous, variable in color, usually some shade of tan or chestnut, often pink or purplish when young; margin entire, concolorous; context white, often tinged with pink where wounded, at first firm, but soft and yielding in older specimens, decidedly bitter, especially when young, sometimes losing its bitter taste with age; tubes adnate, depressed, one to two centimeters long, slender, white, colored at maturity with the flesh-colored spores, mouths angular, of medium size, edges thin, entire; spores fusiform, smooth, flesh-colored, 8–11×3–4μ; stipe cylindric, enlarged below, glabrous, subconcolorous, usually reticulate above, and sometimes entirely to the base, firm, solid, becoming spongy in large specimens, five to twelve centimeters long, one and one-half to two and one-half centimeters thick.

Found abundantly on the ground in woods throughout temperate North America, often reaching a foot in diameter. It may be recognized by its pinkish tubes and usually very bitter flavor, which is not destroyed by cooking. It is therefore inedible, although not generally considered poisonous.

Ceriomyces crassus Batt. Edible. *Boletus edulis* Bull. *Boletus separans* Peck. *Edible Boletus*, (Plate XXXIV, Fig. 5.)—Pileus thick, broadly convex, gregarious or cespitose, six to twenty centimeters broad, three to four centimeters thick; surface smooth, glabrous or finely tomentose, subopaque, dry, slightly viscid when moistened, sometimes pitted or reticulate-rimose, varying in color from ochraceous-brown to reddish-brown, sometimes paler; margin acute, entire; context compact, two to three centimeters thick, unchanging, white or yellowish, sometimes reddish beneath the cuticle, taste sweet and nutty; tubes adnate, at length depressed, plane in mass, white and stuffed when young, yellow or greenish-yellow when mature, changing to greenish-ochraceous when wounded, about two centimeters long, mouths of medium size, angular, edges thin; spores fusiform, smooth, greenish-yellow to ochraceous-brown, 12–15×5–6μ; stipe subequal or enlarged below, stout, concolorous or considerably paler, becoming bluish or discolored when wounded, wholly or partially reticulate, solid, tough, fibrous, yellowish within, tinged with red at times near the surface, five to ten centimeters long, three to four centimeters thick.

This excellent edible species is abundant, well-known, and widely distributed in thin woods throughout temperate regions. The sporophore is large and usually yellowish-brown, while the stipe is more

or less reticulate, especially above. In one variety, the stipe is reticulate to the base, and in another the stipe, as well as the cap, is brownish-lilac in color. It may be distinguished from *Tylopilus felleus* by its mild flavor and differently colored tubes. This species is much used in Europe, and is often sliced and dried for winter use. It is best baked in a covered dish for an hour, after removing the tubes and stipe and cutting it into small pieces.

Ceriomyces scaber (Bull.) Murrill. Edible. *Boletus scaber* Bull., *Rough-stemmed Boletus.* (Fig. 2659.)—Pileus convex, three to twelve centimeters broad; surface very variable in color, white, red or brown, usually

Fig. 2659.—Ceriomyces scaber.

smooth and glabrous; context white, becoming slightly darker or flesh-colored when bruised; tubes long, slender, depressed about the stipe, white or stramineous, becoming brownish with age and flesh-colored or blackish when bruised; spores oblong, smooth, brown, 13–16μ long; stipe firm, solid, tapering upward, whitish, roughened with numerous reddish or brownish dots or scales.

This is a very handsome edible species and the most abundant of the fleshy tube-bearing fungi, being found on the ground in woods or groves from June to November.

Ceriomyces ferruginatus (Batsch) Murrill. Poisonous. *Boletus piperatus* Bull., *Peppery Boletus.*—Pileus convex to plane or nearly so, umbonate when young, circular in outline, two to five centimeters broad, reaching seven centimeters at times; surface smooth, glabrous, sometimes rimose-areolate, slightly viscid in damp weather, varying from ochraceous to fulvous; margin regular, entire, sometimes quite thick because of the lengthening of the marginal tubes; context thickest at the center and gradually thinner toward the margin, yellow or yellowish-white for the most part, but light pink or roseous next to the layer of tubes, darker when exposed to the air, acrid and peppery, remarkably free from insects; tubes adnate, at length depressed around the stem, latericeous, becoming slightly darker when wounded, tinged with ferruginous at the maturity of the spores, equal to or longer than the thickness of the context, mouths large, angular, unequal; spores subfusiform, ferruginous, 9–11$\times$4μ; stipe central, slender, nearly equal, two to five centimeters long, four to five millimeters thick, rarely reaching seven centimeters in length and eight millimeters in thickness, pulverulent, slightly veined above, smooth below, usually somewhat paler than the pileus, citrinous or flavous at the base, solid, fleshy, and yellow within.

This small species occurs rather rarely throughout the Northern United States and Canada in woods and open places near woods. It may be recognized by its yellow cap, acrid and peppery context, and brick-colored tubes. Stevenson pronounced it poisonous, but McIlvaine claims that it loses its peppery taste on cooking and becomes harmless.

Ceriomyces miniato-olivaceus (Frost) Murrill. Poisonous. *Boletus miniato-olivaceus Frost. Sensitive Boletus.*—Pileus firm, convex, becoming nearly plane and somewhat spongy with age, cespitose, becoming olivaceous or ochraceous-red, changing to blue when handled; margin acute, slightly exceeding the pores; context pale-yellow, changing immediately to blue when wounded, mild or slightly unpleasant to the taste, said to be poisonous; tubes adnate or subdecurrent, slightly depressed, bright lemon-yellow tinged with green, becoming brownish-yellow with age, changing to blue when wounded, mouths subangular, of medium size; spores oblong-ellipsoid, smooth, yellowish-brown, 10–13$\times$4–6μ; stipe equal or enlarged above or below, pale-yellow with pink markings, especially near the base, glabrous, faintly reticulate at the top, solid, yellow within, six to ten centimeters long, one-half to one and one-half centimeters thick.

Found in open woods or wood borders from Maine to North Carolina. It is easily distinguished among the red boleti by its quick change to blue at any point, either outside or inside, where bruised or even touched with the fingers. This species is recognized as distinctly poisonous to some people, although others can eat it without danger.

Suillellus luridus (Schaeff.) Murrill. Poisonous. *Boletus luridus* Schaeff, *Lurid Boletus.*—Pileus convex, gregarious or subcespitose, five to twelve centimeters broad; surface dry, smooth, glabrous or minutely tomentose, sometimes clothed with rather conspicuous appressed, felted fibers, occasionally rimose-areolate, brown with shades of red or yellow, often bright brownish-red, becoming paler with age; margin thick, obtuse, entire, sometimes slightly differing in color; context firm, whitish to flavous, quickly changing to blue when wounded, sometimes unchanging in older plants, considered somewhat poisonous; tubes nearly free, rarely adnate, plane, or slightly convex in mass, yellow within, changing to dark greenish-blue when wounded, mouths small, circular, cinnabar-red, becoming brownish-orange, darker with age; spores oblong-ellipsoid, smooth, olivaceous when fresh, 11–16$\times$4–6μ; stipe subequal, five to ten centimeters long, one to two centimeters thick, usually furfuraceous or punctate, at times nearly glabrous, rarely reticulate at the apex or on the upper half, red or reddish-brown below, yellow or orange above, the dots rosy or dark red, solid, yellow within, varied with red or purple.

This is one of the most variable species in the family of fleshy, terrestrial, tube-bearing fungi, but the small genus to which it belongs is readily recognized by its red or reddish tube-mouths, and all of its species should be avoided by mushroom eaters until their properties are better known. This particular species is said to contain a small amount of muscarin or closely allied alkaloid, as well as choline, although it is often eaten. When cut, the entire cut surface of the cap, tubes, and stem changes at once to blue. It occurs in abundance throughout temperate North America and Europe on clay banks or roadsides in open deciduous woods.

Rostkovites granulatus (L.) P. Karst. Edible. *Boletus granulatus* L., *Granulated Boletus.*—Pileus subhemispheric to nearly plane, gregarious, rarely cespitose or solitary, four to ten centimeters broad, one to one and one-half centimeters thick; surface very viscid, with easily separable cuticle, very variable in color, usually pinkish-gray to reddish-brown fading

to yellowish, often obscurely spotted, especially at the center; margin sterile, projecting, incurved and somewhat appendiculate when young; context thick, compact, elastic, pale-yellow next to the tubes, white above, unchanging when wounded, taste mild, somewhat mucilaginous; tubes short, less than five millimeters, adnate, subdecurrent, plane in mass, simple, subcircular, irregular, edges rather thick, flecked with pinkish-brown glandules; spores fusiform, pale yellowish-brown, 7.5–9.5×2.5–3.5μ; stipe short, thick, subequal or enlarged below, white or pale yellow, dotted with pinkish-brown droplets which become darker on drying, solid, white within, two and one-half to five centimeters long, one to one and one-half centimeters thick.

This abundant and widely distributed species occurs from midsummer until frost in sandy open ground under or near conifers. *Rostkovites subaureus*, with yellow cap usually streaked with red, often grows with it in eastern North America. Both are among our finest edible species and can hardly be mistaken for dangerous kinds. *Boletus luteus*, another edible species, has the granulated stipe and the same general appearance, with the addition of an annulus

Strobilomyces strobilaceus (Scop.) Berk. Edible. *Pine-cone Boletus.* (Fig. 2660.)—Pileus hemispheric to expanded, five to ten centimeters broad; surface dry, soft and spongy, blackish-umbrinous, adorned with thick, projecting, floccose, squarrose, blackish scales;

Fig. 2660.—Strobilomyces strobilaceus.

margin fringed with scales and fragments of the veil; context white or whitish, changing to red and then to black when wounded, mild to the taste, edible; tubes adnate, often depressed, white or cinereous, changing like the context when wounded, becoming brown or blackish with age, mouths large, angular; spores subglobose, asperulate, blackish-brown, 8–11μ long; stipe equal or slightly tapering upward, sulcate-striate at the apex, densely floccose-tomentose, brown or blackish below, lighter above, solid, firm, fragile, six to twelve centimeters long, one to two centimeters thick; veil dense, cottony, white to grayish, adhering to the margin and to the stipe in mature plants.

This common edible species is known by its black color and shaggy appearance. Its flesh is white, changing to reddish and finally to black when wounded. It is abundant on shaded banks in woods throughout temperate North America.

Agaricaceæ.—Gill-fungi are usually divided into groups based on the color of their spores as seen under a microscope or in mass on a piece of paper upon which a mature pileus has rested, gills downward, for an hour or more. The spore-prints thus obtained will be found to be variously colored, white, yellowish, rosy, ochraceous, rusty, brown, purplish-brown, and black. The white-spored, brown-spored, and black-spored groups contain most of the recognized edible and poisonous species.

Chanterel chantarellus (L.) Murrill. Edible. *Cantharellus cibarius* Fries, *Edible Chanterel.* (Plate E, Fig. 4.)—Pileus fleshy, firm, turbinate, nearly plane, sometimes depressed, gregarious, cespitose at times, three to eight centimeters broad; surface glabrous, luteous, rarely paler yellow, margin involute to expanded, undulate; context white, nutty or slightly acrid, edible; lamellæ thick, narrow, distant, decurrent, forked or irregularly anastomosing, luteous, or sometimes much paler; spores ellipsoid, somewhat irregular, smooth, pale-ochraceous, 8–10×4–5μ; stipe attenuate below, glabrous, concolorous or paler, solid, two and one-half to five centimeters long, six to twelve millimeters thick.

Common throughout temperate regions in deciduous or coniferous woods, especially in dense evergreen thickets, appearing in midsummer. It is egg-yellow all over, and has peculiar narrow, blunt, decurrent lamellæ. It has long held a high reputation for edibility, and the only poisonous species with which it may easily be confused is *Chanterel aurantiacus.* It should be stewed for nearly an hour and seasoned with butter or meat gravy. It is an excellent addition, also, to hashes, meat stews, and omelets.

Chanterel aurantiacus (Wulf.) Fries. Doubtful. *Orange Chanterel, False Chanterel.* (Fig. 2661.)—Pileus compressed, hemispheric to funnel-shaped, convex to expanded, plane to depressed, fleshy, flexible, gregarious to subcespitose, three to six centimeters broad; surface subtomentose, pale-orange, often darker at the center, margin involute, entire to undulate; lamellæ decurrent, crowded, narrow, rather thin, regularly and two to four times dichotomous, bright orange; spores ellipsoid, smooth, hyaline, 5–7×3–4μ; stipe usually central, cylindric, enlarged below, slightly ascending, two to five centimeters long, four to seven millimeters thick, subglabrous above, tomentose below, stuffed, subconcolorous, varying to pallid or dark brown.

In woods, on decayed wood, or on soil rich in humus, from Canada to South Carolina and Nevada. It was long considered dangerous, but very recently Sartory investigated it in France and declared it harmless. Later, Dr. Peck tried it and added it to his list of edible species. I still believe it is slightly poisonous to some and should be eaten with caution if at all, but it is gratifying to know that amateur mycophagists may now eat *Chanterel chantarellus* without very much risk.

Lactaria.—Many species of this genus were formerly considered poisonous on account of their acrid taste, but, since it has been found that these peppery, resinous substances are usually decomposed on cooking, it will be necessary to make an experimental revision of the genus. *Lactaria rufa* seems to enjoy the worst reputation, from all accounts, while *L. torminosa, L. fuliginosa, L. vellerea, L. pyrogala,* and *L. theiogala* are either pronounced poisonous or

suspicious by most authors. Care should be exercised in collecting members of this genus for the table. The harmful species may usually be distinguished by their acrid flavor.

Lactaria deliciosa (L.) Fries. Edible. *Delicious Lactaria.*—Pileus fleshy, convex-umbilicate, becoming plane, then infundibuliform, five to twelve centimeters broad; surface orange, yellow-orange or paler, zoned with deeper orange, becoming paler with age, sometimes mixed with grayish and greenish tints, viscid when wet, glabrous, somewhat roughened; margin involute, then arched and at length upturned, glabrous; context firm, yellowish, often staining greenish next the lamellæ and the exterior of the stipe; edible; latex orange to red-orange, aromatic and somewhat acrid; lamellæ deep-orange with yellowish reflections, paler when old, often becoming greenish with age or where bruised, many forking near the stipe, and shorter ones branching into longer ones, often connected with cross veins at the base, close, somewhat decurrent, rather narrow; stipe of the same color as the pileus, spotted with brighter orange, nearly equal, glabrous, or sometimes a little tomentose at the base, smooth, stuffed, becoming hollow, two and one-half to ten centimeters long, eight to twelve millimeters thick; spores yellow, subglobose to ellipsoid, slightly echinulate, more or less hyaline, 8–8.5×8–11μ.

strong, persisting odor, edible; latex white, unchanging, mild, sticky, abundant; lamellæ creamy-white or tinged with the same color as the pileus, becoming darker with age, changing brownish where injured, often forking two or three millimeters from the stipe or midway to the margin, close, adnate, two to five millimeters broad; stipe of nearly the same color as the pileus but paler, nearly equal, glabrous, pruinose, solid, sometimes becoming hollow, two to ten centimeters long, one to two centimeters thick; spores white, globular, echinulate, 7–10μ in diameter; cystidia 20–35μ long, colorless or yellowish.

Common in woods and groves, especially near oak trees, throughout the eastern United States. When raw, the flavor is somewhat unpleasant and astringent, but it is fairly good when cooked slowly for forty minutes. It should be very carefully distinguished from the poisonous *Lactaria rufa*, which is bay-red to rufous and very acrid.

Lactaria piperata (L.) Pers. Edible. *Peppery Lactaria.* (Fig. 2662.)—Pileus fleshy, convex-umbilicate, at length infundibuliform, four to twelve centimeters or more in diameter; surface white, azonate, dry, glabrous; margin involute at first and naked, at length uplifted; context compact, white, unchanging or becoming sordid, edible; latex white, unchanging, very acrid, abundant; lamellæ white or creamy-white forking dichotomously, close, more or less decurrent

Fig. 2661.—Chanterel aurantiacus.

In moist woods, especially under firs and hemlocks, in mountainous regions throughout most of the United States, but not so common as in Europe. Long considered one of the best mushrooms and readily recognized by its orange-red milky juice, which becomes greenish on exposure to the air. It should be cooked slowly for nearly an hour.

Lactaria lactiflua (L.) Burl. Edible. *Lactaria volema* Fries, *Orange-brownlactaria.* (Plate XXXIV, Fig. 10.)—Pileus fleshy, convex, then nearly plane or slightly depressed, five to thirteen centimeters broad; surface fulvous, buff, or brownish-terra-cotta to brownish-orange, sometimes much paler, azonate, dry, glabrous, smooth, or at length rimose-rivulose; margin involute at first, then extended; context firm, thick, whitish, changing brown where exposed to the air, having a

arcuate at first, then extending upward, only about two millimeters broad; stipe white, equal, dry, often pruinose, solid and firm, two to eight centimeters long, up to two centimeters thick; spores white, subglobose, nearly smooth, 8–9μ in diameter.

Found in great abundance in oak woods throughout temperate North America. It contains an acid and a resin, "piperon," which is extremely acrid in the fresh state, but is disorganized by heat. This species is therefore harmless when cooked, but is coarse and poorly flavored. If eaten, it must be carefully distinguished from poisonous species that are acrid in the fresh state.

Russula.—Most of the members of this genus are edible, and some of them are particularly good, but they are usually scattered, are fragile and perishable,

become infested early with a variety of insects, are eaten by squirrels and other animals, and resemble one another so closely that it is advisable to go to the trouble of tasting nearly every specimen before selecting it for the table. There are no violently poisonous species known in this genus, and if specimens have mild taste and an agreeable odor they are probably harmless, but it must always be remembered that it is necessary to test each new species thoroughly before using it in any quantity for food. *Russula emetica* is poisonous, containing choline, pilz-atropine,

Fig. 2662.—Lactaria piperata. Very acrid raw, but edible when cooked.

and probably muscarine; *R. fœtens* is also poisonous, but in a lesser degree; while *R. nitida, R. fragilis,* and other species belong to the mildly poisonous or suspected class. No experiments will be of great value until the genus is better known botanically.

Russula mariæ Peck. Edible. *Mary's Russula.*—(Plate XXXIV, Fig. 3) Pileus fleshy, convex and subumbilicate to depressed, reaching seven centimeters broad; surface dry, rosered or purple with darker disc, having a bloom like a peach, margin slightly striate at times, especially in old plants; context thin, of good flavor, white, pinkish under the cuticle, odor not characteristic; lamellæ white or stramineous, broad, subcrowded, interveined; spores subglobose, minutely conic-tuberculate, yellow, 7μ; stipe equal, solid, rosy, sometimes partly white, glabrous, about one and three-tenths to one and one-half centimeters thick.

This is one of our prettiest species, and it may be looked for under oaks anywhere in the eastern United States after summer rains. It is distinguished from poisonous species similar in color by its mild flavor when raw.

Russula emetica Fries. Poisonous. *Emetic Russula.* (Plate P. Fig. 1.)—Pileus regular, firm to fragile, convex to plane or depressed, five to eight centimeters broad; surface viscid when young, polished, red, often fading to pallid or yellowish, cuticle separating very readily; context white, reddish under the cuticle, very acrid to the taste; lamellæ white, then dull-yellowish, free, subdistant, broad, equal; spores globose, echinulate, hyaline, 8–10μ; stipe rosy or whitish, glabrous, spongy-solid, three to seven centimeters long, one to one and one-half centimeters thick.

Common in woods throughout Europe and the eastern United States, often growing where logs have decayed. Distinguished by its red color, viscid surface, readily separating cuticle, and very acrid taste. In addition to its acrid quality, it is definitely poisonous, containing small quantities of choline, pilz-atropine, and probably muscarine. When taken in any quantity, it acts as a prompt emetic. It is mainly because of this species that most specimens of *Russula* should be tasted before selecting them for food.

Russula virescens (Schaeff.) Fries. Edible. *Green Russula.*—Pileus convex to expanded, at length depressed, solitary, five to ten centimeters broad; surface dry, greenish, marked with small angular areas or patches; context white, firm, mild-flavored; lamellæ adnate, crowded, white; stipe rather short, white, glabrous, two to six centimeters long, one to two centimeters thick.

This beautiful woodland species has long enjoyed a reputation for edibility, but, unfortunately, it is rather rare and its flavor is not really of first rank. It may be recognized by the greenish color and warted appearance of its pileus. The pileus of *Russula furcata*, a bitter species formerly considered poisonous, is green but not warted. The green form of *Amanita phalloides* and the poisonous *Entoloma lividum*, both common in Europe, are easily distinguished by other characters.

Russula fœtens Pers. Poisonous. *Fetid Russula.* (Plate XXXV, Fig. 2.)—Pileus firm, rather thin, globose to plane or slightly depressed, five to ten centimeters broad; surface very viscid, slimy, conspicuously striate-tuberculate, ochraceous-melleous, testaceous-fulvous in the center with small bay or blackish areas; context whitish, tardily acrid and mucilaginous to the taste, with odor of prussic acid; lamellæ mostly equal, adnate or adnexed, subcrowded, arcuate, white, staining brownish when injured, usually decorated with small drops of water when the air is damp; spores globose, strongly echinulate, hyaline, 10μ; stipe cylindric, equal or somewhat ventricose, glabrous or subglabrous, white, staining brownish when injured, hollow, five to eight centimeters long, one to two centimeters thick.

This conspicuous species is common under oaks in groves or woodlands throughout most of Europe and the United States, sometimes occurring in great quantity in one spot. Its odor is similar to that of peach kernels, and in some specimens it is strong and unpleasant, although at times it may be scarcely noticeable. This unpleasant odor and the very slimy character of the surface render the plant unattractive and one would hardly collect it for food. It is known to be definitely poisonous to a certain extent and should always be avoided by mycophagists.

Marasmius oreades (Bolt.) Fries. Edible. *Fairy-ring Mushroom. Scotch Bonnets.* (Plate XXXIV, Fig. 8.)—Pileus convex to expanded, often umbonate, slightly striate at times when moist, fleshy-tough, drying easily, two to five centimeters broad; surface glabrous, buff or tawny, fading with age or on drying; context thin, white, of pleasant odor and taste; lamellæ broad, distant, free or adnexed, yellowish-white; spores subellipsoid, smooth, hyaline, 7–9μ long; stipe cylindric, rather slender, solid, tough, yellowish-white, villose-tomentose, five to eight centimeters long, two to four millimeters thick.

This very excellent little species is to be looked for in pastures during spells of wet weather in late summer or autumn. Its habit of growing in circles will aid one in recognizing it. I have found it much more abundant in England and other parts of Europe than in this country. If found in sufficient quantity for table use, it should be cooked for some time, owing to its tough texture. One should be very careful in picking small fungi growing on lawns for table use, to avoid getting *Marasmius urens; Inocybe infida*, a dangerous species with yellowish-brown spores; and certain species of *Panæolus* having black spores.

Pleurotus sapidus Kalchb. Edible. *Sapid Pleurotus, False Oyster Mushroom.* (Fig. 2663.)—Pileus convex or nearly plane, irregularly fan-shaped, eccentrically or laterally stipitate, cespitose, imbri-

EXPLANATION OF
PLATE XXXV.

EXPLANATION OF PLATE XXXV.

SOME POISONOUS MUSHROOMS.

FIG. 1.—Russula emetica

FIG. 2.—Russula fœtens

FIG. 3.—Suillellus luridus

FIG. 4.—Venenarius phalloides, yellow and brown forms

FIG. 5.—Venenarius muscarius, usual form and small pale form

FIG. 6.—Clitocybe illudens

FIG. 7.—Venenarius cothurnatus

FIG. 8.—Inocybe infida

FIG. 9.—Tylopilus felleus

SOME POISONOUS MUSHROOMS (MURRILL)

Fig. 2663.—Pleurotus sapidus.

cate, five to twelve centimeters broad; surface smooth, glabrous, variously colored, usually yellowish or brownish; context white, mild-flavored, somewhat tough; lamellæ broad, white, decurrent, rather distant, reticulate behind; spores white tinged with lilac when shed on paper; stipe eccentric or lateral, rather short, but varying according to position in the cluster.

Very common on dead trunks of deciduous trees, especially elm, from June to November. In Hungary, it is cultivated on sections of elm logs. The oyster mushroom, *Pleurotus ostreatus*, is confused with it in this country and for our present purpose need not be distinguished, as its properties are similar. Both species are rather tough and lack flavor but they occur in such large masses and are so readily recognized that they are to be recommended for general use as food. The young and tender caps should be selected and cooked slowly in a sauce pan for at least twenty minutes. The only similar poisonous species known is the tiny *Panus stypticus* found on the tops of stumps and readily distinguished by its acrid, astringent taste.

Clitocybe multiceps Peck. Edible. *Many-headed Clitocybe.* (Fig. 2664.)—Pileus convex to expanded,

Fig. 2664.—Clitocybe multiceps.

cespitose, three to eight centimeters broad; surface smooth, glabrous, watery-white to pale avellaneous-isabelline, the disc more grayish; context milk-white, mild, somewhat oily, firm, and persistent; lamellæ adnate or slightly decurrent, rarely sinuate, white or pale-stramineous, close, and narrow; spores globose, smooth, hyaline, 5–7μ; stipe cylindric, equal, solid or stuffed, firm, white or pale stramineous, pruinose above, five to ten centimeters long, seven to fifteen millimeters thick.

This species occurs in wet weather in dense clusters on lawns, especially in rather long grass, and is usually found in great abundance when found at all. Its context is firm, with a slight oily flavor, and sporophores may be kept for several days before cooking. It is known only from New York and a few other states, but should stand transplanting in sod rather easily. Having used it in quantity from my own lawn, I can recommend it as a valuable edible species.

Clitocybe illudens (Schw.) Sacc. Poisonous. *Deceiving Clitocybe. Jack-my-lantern.* (Plate XXXV, Fig. 6.)—Pileus convex to plane or depressed, irregular, often umbonate, densely cespitose, ten to twenty centimeters broad; surface glabrous, saffron-yellow; context thick, white or yellowish, becoming sordid with age, with a somewhat disagreeable or bitter flavor and at times a strong odor; lamellæ broad, decurrent, saffron-yellow; spores abundant, globose, hyaline, 4–5μ; stipe long, firm, glabrous, concolorous, tapering toward the base of the cluster.

This species is readily recognized by its large size and brilliant coloring. It occurs throughout the eastern United States from midsummer to autumn in large clusters about dying trunks and stumps of deciduous trees. On dark nights, these clusters and also pieces of dead wood containing the mycelium are usually conspicuously phosphorescent. The plant is distinctly poisonous, showing a muscarine reaction on the nerves of the heart, and producing nausea, vomiting, and diarrhea. As shown in the accompanying graphic records (Fig. 2665), atropine is an antidote for the depressing effects of this poison.

Melanoleuca personata (Fries) Murrill. Edible. *Tricholoma personatum* (Fries) Quél. *Masked Tricholoma. Blewits.* (Plate XXXIV, Fig. 6.)—Pileus thick, firm, convex to expanded, five to twelve centimeters broad; surface moist, glabrous, lilac or purple, fading to grayish, becoming slightly brownish on the disc; margin inrolled and frosted when young, glabrous, and often irregular with age; context white, firm, pleasant to the taste; becoming dull-colored with age; spores ellipsoid, smooth, dingy-white, dull-pinkish in mass, 7–10μ long; stipe short, solid, often bulbous at the base, fibrillose to glabrous, lilac or violet, three to six centimeters long, one and one-half to three centimeters thick.

This valuable species is of excellent flavor and not

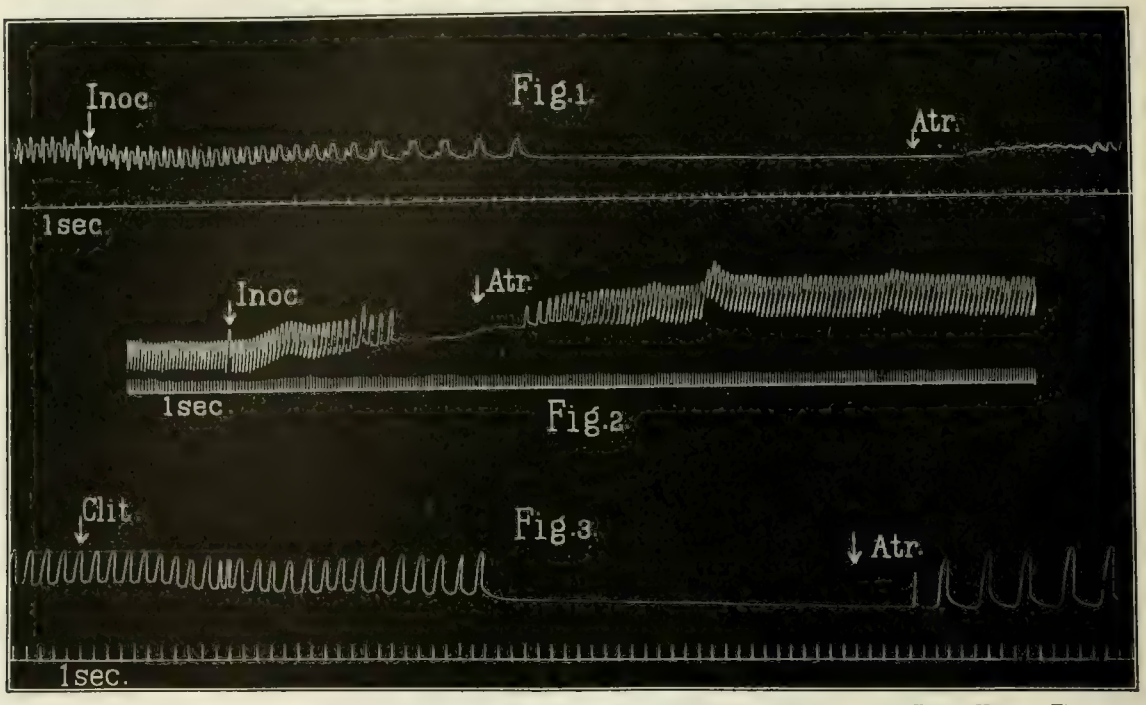


Fig. 2665.—Graphic Records of the Effect of Extracts of *Inocybe infida* and *Clitocybe illudens* on the Frog's Heart. The arrows indicate the time when the extracts and atropine solution were applied to the exposed heart.

easily confused with dangerous species. It may be found in open woods or among long grass in rich fields during the autumn months. Its large size and the violet or lilac tint of all its parts should distinguish it from most other species. In large, mature specimens, the flesh becomes soft and readily absorbs water during wet weather, which somewhat changes the appearance of the mushroom and lessens its value for edible purposes. Only one species of *Melanoleuca*, *M. sulphurea*, with a strong and disagreeable odor, is considered to any extent dangerous, although not all have been tested. Certain species in other genera resembling *M. personata* in color, *Laccaria laccata*, *Laccaria ochropurpurea*, *Cortinarius violaceus*, *Cortinarius alboviolaceus*, and *Lactaria indigo*, are all edible.

Armillaria mellea (Vahl) Quél. Edible. *Honey Agaric.* (Plate XXXIV, Fig. 13.)—Pileus convex to expanded, cespitose, very variable, four to twelve centimeters broad; surface usually dry, smooth or becoming striate toward the margin, pale honey-yellow to dark reddish-brown, usually adorned with minute tufts of brown or blackish hairs, which are more abundant on the disc; context white or whitish, somewhat acrid and unpleasant to the taste; lamellæ adnate or decurrent, white or whitish, becoming discolored or spotted with age; spores ellipsoid, smooth, hyaline, 7–10μ long; annulus white, cottony, with dark specks, or thin, arachnoid, and evanescent; stipe melleous, reddish-brown or dirty-brown below, paler above, nearly equal, firm, fibrous, spongy within, usually floccose-scaly below the annulus, four to twelve centimeters long, five to fifteen millimeters thick.

Very widely distributed and very abundant on stumps and buried roots of both deciduous and evergreen trees, on which it grows as a parasite, the sporophores appearing in dense clusters in autumn and the shining brown cords, or "rhizomorphs," being often seen in dead logs and stumps. Although of inferior quality, it is much used as food. When raw, the flavor is unpleasant, and it was therefore formerly considered poisonous. Only the young and tender caps should be selected.

Fig. 2666.—Lepiota procera.

Lepiota procera (Scop.) Quél. Edible. *Parasol Mushroom.* (Fig. 2666.)—Pileus soft, fleshy, ovoid to expanded, umbonate, solitary or gregarious, eight to sixteen centimeters broad; surface radiate-fibrillose and rufescent beneath the cuticle, the cuticle thick, at first smooth and continuous, whitish or rufous to umber in color, at length torn asunder, except upon the umbo, into large irregular scales which become scattered and gradually fall away, margin deflexed, silky-fibrillose; context thick, soft, white; lamellæ broad, close, white, at times yellowish or pinkish, tapering slightly behind, free, remote; spores ellipsoid or obovoid, apiculate, 1–2-guttulate, 12–18×8–12μ; stipe tall, tapering upward from the bulbous base, hollow or fibrous-stuffed, the cuticle thin, flocculose, rufous or brownish, at length drawn apart into minute scales, fifteen to twenty-five centimeters long, eight to sixteen millimeters thick, the base two to three centimeters thick; annulus thick, soft, subcoriaceous, movable, apical.

white, free, close; spores subellipsoid, smooth, hyaline, uninucleate, 7.5–10×5–7μ; stipe thickened below, white, hollow, seven to twelve centimeters long; veil white, forming an apical annulus.

A conspicuous and easily recognized edible species of wide distribution in America, occurring in groups or clusters on rich lawns or about old stumps, sawdust piles, or compost heaps from midsummer to autumn. *Lepiota morgani*, a poisonous species resembling it in shape, has green spores, causing the lamellæ to assume a green color as they mature.

Lepiota naucina (Fries) Quél. Edible. *Smooth Lepiota.* (Fig. 2668.)—Pileus thick, globose to convex, five to eight centimeters broad; surface dry, usually white and smooth, at times slightly yellowish or granular on the disc; context firm, fleshy, white, mild; lamellæ free, white, dull pinkish with age; spores usually white in mass, rarely tinged with pink; stipe white, smooth, enlarged below, bearing a white

Fig. 2667.—Lepiota americana.

This handsome edible species is found rather sparingly in thin soil in meadows, pastures, and open woods from New England to Alabama and west to Nebraska. It is also widely distributed in Europe and Asia, where it is highly esteemed as an article of food, in some places being dried in quantity for winter use. It should be cooked quickly with dry heat. On account of its scaly cap and bulbous stem, it must be very carefully distinguished from species of *Venenarius*. In *Lepiota*, the scales are a part of the cap and do not separate readily; in *Venenarius*, they are fragments of the roof of the volva and may be easily removed from the cap. The parasol mushroom also differs from species of *Venenarius* in having a free and movable, instead of a fixed, ring, and in having no cup nor fragments of a cup at the base of the stem, although the base is swollen.

Lepiota americana Peck. Edible. *American Lepiota. Blushing Lepiota.* (Fig. 2667.)—Pileus ovoid to convex and at length expanded, umbonate, five to fifteen centimeters broad; surface white, umbo and scales reddish-brown, the entire plant becoming reddish-brown when wounded or on drying; lamellæ annulus above, six to ten centimeters long, eight to sixteen centimeters thick.

This excellent species occurs in the autumn in lawns and pastures where the common mushroom grows and is often picked and thrown away because the lamellæ are white. There is no harm in using it for food if the collector and those who may imitate him distinguish it carefully from the white variety of *Venenarius phalloides*, which is so common in this region and has been the cause of most of the deaths among mushroom eaters in the vicinity of New York City. It must be remembered that this deadly species is picked by some persons for the common mushroom, in spite of its white lamellæ and bulbous stipe. How much more easily might *Lepiota naucina*, which has both characters, be confused with it! The deadly *Amanita phalloides* may be distinguished from *Lepiota naucina* by the "death-cup" at the base of the stipe, by the longer and usually more bulbous stipe, and by the gills remaining white instead of becoming slightly dull pinkish with age.

Chlorophyllum molybdites Mass. Poisonous. *Lepiota Morgani Peck. Green-spored Lepiota.*—Pileus

Fig. 2668.—Lepiota naucina.

Fig. 2669.—Vaginata plumbea.

fleshy, at first globose then convex and expanded or depressed, gregarious or in rings, ten to twenty centimeters broad; surface white beneath the cuticle, radiate-fibrillose, the cuticle at first continuous, buff to pale umber, soon broken up, except in the center, into irregular scales and patches, which are gradually drawn apart and at length are more or less deciduous; context thick, firm, white, changing to reddish when bruised, poisonous to some persons; lamellæ rather broad, ventricose, close, remote from the stipe, at first white then changing to a greenish hue, at length dull green; spores in mass at first bright green, fading to dull green and becoming sordid with age, subellipsoid, obliquely apiculate, uniguttulate, 7–11×5–6μ; stipe hard and firm, tapering upward from the thickened base, fistulose, fibrous-stuffed, the surface glabrous, white or buff to pale umber, ten to twenty centimeters long, one to two centimeters thick at the apex, two to four centimeters thick at the base; annulus thick, ample, soft, subcoriaceous, movable, apical.

Found in meadows, pastures, fields, and open woods from New Jersey to Iowa and southward to Texas, the West Indies, and Brazil. It sometimes occurs in large fairy rings on lawns. It may be readily distinguished from *Lepiota americana* and other species of that genus by its green spores, which soon color the lamellæ green. It is harmless to some persons, but distinctly poisonous to others, though never fatal. Old specimens appear to contain more poison than young ones.

Vaginata plumbea (Schæff.) Murrill. Edible. *Amanitopsis vaginata* P. Karst. *Sheathed Amanita.* (Fig. 2669.)—Pileus thin, fragile, campanulate to expanded, three to eight centimeters broad; surface dry, glabrous, deeply striate on the margin, exceedingly variable in color, ranging from nearly white to reddish-brown; lamellæ free, fragile, white; spores globose, smooth, hyaline, 8–10μ; stipe nearly equal, scarcely enlarged below, glabrous or adorned with minute scales, variable in color, hollow or stuffed within, six to twelve centimeters long, four to eight millimeters thick, entirely devoid of a ring, but conspicuously sheathed at the base with a long, loose, white volva, portions of which are sometimes carried up as patches on the cap.

This attractive and very variable species is abundant in woods throughout Europe and North America during summer and autumn, and possesses excellent edible qualities. It may be distinguished from species of *Venenarius*, some of which are deadly poisonous, by the total absence of a ring on the stem, although the conspicuous volva at the base suggests its close relationship to that genus. The variations in color presented by this species are often very bewildering to the beginner, and it must be selected with great care to avoid confusing it with poisonous species.

Vaginata agglutinata (Berk. & Curt.) O. Kuntze. Poisonous. *Amanitopsis volvata* (Peck) Sacc. *Large-sheathed Vaginata.* (Fig. 2670.)—Pileus hemispheric to plane, sometimes slightly depressed, very variable in size, two to eight centimeters broad; surface dull white or yellowish, rarely reddish-brown at the center or entirely reddish-brown, pulverulent, floccose-squamose, or with large volval patches; lamellæ free, rounded behind, broad, crowded, white; spores ellipsoid, smooth, hyaline, 10–12×6–7μ; stipe very variable in size, one to seven centimeters long, three to eight millimeters thick, equal or tapering upward, enlarged at the base, whitish, minutely floccose-squamose, stuffed or solid; volva unusually large, firm, membranous, persistent, more or less lobed.

Found in open woods and wood borders from New England to Alabama and west to Ohio. It varies much in size, and its surface may be entirely glabrous or adorned with a few large patches from the immense volva, or covered with powder. Ford says it is poisonous, and, even if it were edible, it is too much like poisonous species of *Venenarius* to be recommended.

Fig. 2670.—Vaginata agglutinata.

Venenarius.—The genus *Venenarius* is distinguished from all other white-spored genera by the presence of a universal veil which encloses the entire sporophore in its young stage and remains either at the base of the stipe or as warts on the surface of the pileus when the sporophore is mature. Over thirty American species are listed, but hardly half of them are worthy of the rank, and only about half a dozen of these are known to be deadly poisonous.

Venenarius phalloides (Fries) Murrill. Deadly Poisonous. *Amanita phalloides* Fries. *Deadly Amanita. Destroying Angel.* (Figs. 2671, 2672; and Plate XXXV, Fig. 4.)—Pileus convex or campanulate to

Fig. 2671.—Venenarius phalloides; white form, young stages, showing cap bursting from the volva and the forms of the young veil.

expanded, three to fifteen centimeters broad; surface smooth, slightly viscid when moist, glabrous or decorated with scattered patches of the volva, varying in color from pure white to yellow, yellowish-green, green, gray, brown, or blackish, margin rarely striate; context extremely poisonous, white, not objectionable to the taste but having at times a somewhat disagreeable odor; lamellæ white, unchanging, broad, ventricose, rounded at the base

and free or adnexed; spores globose, smooth, hyaline, 7–10μ; stipe subequal, bulbous, long, smooth or floccose-scaly, usually white, stuffed or hollow, six to fifteen centimeters long, one-half to one and one-half centimeters thick; annulus superior, membranous, thin, ample, persistent or at times becoming torn away, usually white; volva white, adnate to the base of the large, rounded bulb, the limb usually free,

Fig. 2672.—Venenarius phalloides; white form known as "the destroying angel."

conspicuous, lobed, thick and fleshy, persistent, but at times breaking partly or wholly into irregular patches that are either carried up on the surface of the pileus or remain at the base of the stipe.

This most deadly species, for which no antidote is known, occurs widely distributed in many forms and colors, but is always distinguished by the presence of a distinct volva or death-cup at the base of the stipe. The principal poison is not accurately known chemically, neither have its exact effects on the animal system been determined, although many attempts to do so have been made both by physiologists and chemists. It is reasonable to expect that at no very distant date an antidote will be discovered for the deadly amanita, as has been the case with rattlesnake poison and the toxin accompanying diphtheria. The effects of the poison are rather slow to appear, usually from six to fifteen hours, when there is sudden and severe pain in the abdomen followed by loss of strength and of flesh, and the patient gradually sinks into profound coma and dies in from three to eight days if the amount taken has been sufficient. Convulsions are not usual with this kind of poisoning.

It is frequently stated that poisons may be removed from mushrooms by boiling them in water and throwing the water away. This may be true of some species, but it is by no means true of the deadly amanita. This species has only recently been subjected to severe tests with both dry heat and steam without disorganizing or extracting the poison from the substance of the cap.

The variety of colors assumed by this species—white, yellow, green, gray, brown, blackish—and the fact that the annulus and the limb of the volva may sometimes be lost, make it necessary to use great caution in selecting any white-gilled species with bulbous stipe for food, whether an annulus is present or not. All species of *Venenarius* and *Vaginata*, and several species of *Lepiota*, must be examined with great care.

Venenarius muscarius (L.) Earle. Deadly Poisonous. *Amanita muscaria* (*L.*) Pers. *Fly Amanita. Fly Agaric. Fly Poison.* (Plate XXXV, Fig. 5.)—Pileus globose to convex, at length nearly plane, eight to twenty centimeters broad; surface slightly viscid when fresh, red or orange to yellow, rarely paler, adorned with numerous whitish or yellowish warts, margin slightly striate; context white, yellow under the pellicle, extremely poisonous; lamellæ white, rarely pale yellowish, rather broad, reaching the stipe and forming slight decurrent lines upon it; spores subglobose to ellipsoid, 9–10$\times$7–8μ; stipe subequal, white or pale yellowish, stuffed or hollow, usually rough with concentric, margined scales adnate to the bulbous base, eight to twenty-five centimeters long, two to three centimeters thick; annulus superior, large, membranous, persistent, white; volva white or yellowish, usually entirely fragile, rarely slightly margining the bulb.

Widely distributed in woods, wood borders, and thickets throughout temperate regions, being especially abundant under and near pine trees. It is a strikingly beautiful plant and all the more dangerous because of its beauty. Its colors are usually paler here than in Europe. Italians have often mistaken it for the royal agaric, and it is even picked at times by the ignorant for *Agaricus campester.* The volva usually breaks up very early, so that a definite cup is rarely seen at the base of the stipe, but the fragments of the volva are conspicuous on the surface of the pileus.

This species has been celebrated for centuries on account of its poisonous properties due to the alkaloid muscarine, which affects the ganglia controlling the nerves of the heart and thus retards and finally stops its action if taken in sufficient quantity. Atropine has the opposite effect on the heart, and has therefore been successfully used as an antidote for muscarine. Other heart stimulants have also been used. The effects of the poison are slow to appear unless taken in quantity. Convulsions are often among the symptoms. Atropine should be administered by the attending physician as quickly as possible. The literature of this species is more extensive than that of all other poisonous species combined. It was formerly widely used as a fly poison; and is still used in certain parts of Russia as an exhilarant. It is celebrated in history because of its long and distinguished list of victims. It has been chemically investigated more often and more successfully than any other species, and a perfect antidote for its principal poison has been discovered.

Venenarius cothurnatus (Atk.) Murrill. Poisonous. *Amanita cothurnata* Atk. *Booted Amanita.*—Pileus globose to convex, at length expanded, three to seven centimeters broad; surface quite viscid when moist, decorated with small, scattered, soft, floccose warts, white or tinged with lemon-yellow, or with the center tawny-olive, even or finely striate on the margin; context white, without odor; lamellæ rounded behind, crowded, plane, white; spores globose, smooth, hyaline, 7–9μ; stipe cylindric, bulbous, flocculose or floccose-scaly, white, hollow or rarely

stuffed, five to twelve centimeters long, two-fifths to one centimeter thick; annulus white, thick, persistent, volva white, adnate to the large, ovoid bulb, circumscissile, breaking uniformly and leaving an abrupt ring at the top of the bulb.

Found in woods from New York to Alabama and west to Pennsylvania and Tennessee. I have noticed that it has the same effect upon flies as *V. muscarius*. Its close relative, *Venenarius pantherinus*, is considered poisonous by all authors, causing intoxication similar to that caused by *V. muscarius*, though in milder form, and containing both muscarine and choline. It is said to be the chief poisonous mushroom of Japan, but has been rarely known to be fatal.

Venenarius spretus (Peck) Murrill. Poisonous. *Amanita spreta* Peck. *Sheathed Venenarius.*—Pileus subovoid to convex, at length expanded, seven to twelve centimeters broad; surface white or pale grayish-brown, subviscid, glabrous or with few volval fragments, faintly striate on the margin; lamellæ adnexed, subcrowded, rather narrow, white; spores ellipsoid, smooth, hyaline, 10–12×6–8μ; stipe cylindric, equal, not bulbous at the base, smooth, nearly glabrous, slightly pruinose at the apex, white, solid, or stuffed, seven to ten centimeters long, about one and one-half centimeters thick; annulus membranous, persistent, white, attached about one to two centimeters from the apex of the stipe; volva thin, membranous, ample, persistent, closely sheathing but not adnate.

Found sparingly in open or bushy places from Maine to Alabama in the eastern United States. This species is poisonous, according to Ford, and it must be remembered when collecting *Vaginata plumbea* for food, since the sheaths in the two species are very similar.

Venenarius solitarius (Bull.) Murrill. Poisonous. *Amanita solitaria* Fries. *Amanita strobiliformis* Vitt. *Warted Amanita. Pine-cone Amanita.*—Pileus subglobose or convex to plane, solitary, five to twenty centimeters broad; surface dry, usually white or slightly yellowish, rarely cinereous or murinous, densely pulverulent, or pelliculose adorned with seceding, angular warts that may be soft, floccose and flattened, or firm and erect, often becoming glabrous with age, margin smooth, at times appendiculate; context firm, white, usually of mawkish flavor and odor resembling that of chlorine; lamellæ usually adnexed and rather narrow, occasionally free and rounded behind, more or less crowded, white; spores ellipsoid, smooth, hyaline, very variable in size, 7–14×5–9μ; stipe subequal, usually radicate, bulbous or enlarged or equal below, concolorous or paler, mealy above, squamulose or imbricate-squamose below, solid or slightly spongy, four to fifteen centimeters long, one to four centimeters thick; annulus white, apical, fragile or lacerate, often appendiculate or evanescent; volva white, usually friable, rarely remaining as concentric, margined scales or a short limb at the base of the stipe.

An exceedingly variable species, usually white and scaly and often with a chlorine odor, occurring in the open or in thin woods throughout most of the United States. It has been considered edible, but Ford finds that it contains a small quantity of the deadly amanitatoxin found in *Venenarius phalloides* and it should therefore never be eaten.

Venenarius rubens (Scop.) Murrill. Edible. *Amanita rubescens* Pers. *Blushing Amanita.*—Pileus ovoid to convex, at length expanded, six to twelve centimeters broad; surface adorned with numerous thin, floccose or farinose warts, variable in color, always tinged with reddish or brownish-red, changing slowly to reddish when bruised, margin smooth or faintly striate; context white, changing slowly to reddish when bruised, with a pleasant odor and taste; lamellæ free or slightly adnexed, crowded, nearly plane, white, characteristically chalky-white when dry; spores ellipsoid, smooth, hyaline, 10–11×6–7μ; stipe [equal or slightly tapering upward, usually bulbous, squamulose, whitish suffused with red, becoming reddish when bruised, stuffed, six to twenty centimeters long, six to twelve millimeters thick; annulus superior, ample, white, easily torn; volva very fragile, most of the fragments appearing on the surface of the pileus, while a few remain clinging to the margin of the bulb.

Found commonly in woods and groves from Maine to Alabama and west to Ohio. It contains poisons when raw, but these are disorganized by cooking or digestion. Although edible, I cannot advise any one to eat it, since many of its near relatives are so deadly. It might easily be confused with *Venenarius muscarius*, for example.

Venenarius cæsareus (Scop.) Murrill. Edible. *Amanita cæsarea* Pers. *Cæsar's Agaric. Royal Agaric.*—Pileus hemispheric to expanded, eight to sixteen centimeters broad; surface red, orange, or yellow, rarely pale yellow, smooth, shining, occasionally decorated with a patch from the volva, margin thin, deeply striate; context yellow, unchanging, mild and agreeable to the taste, odor none; lamellæ free, subcrowded, bright yellow; spores ellipsoid, smooth, hyaline, 8–10×6μ; stipe cylindric or subventricose, not bulbous at the base, white or pale yellow, slightly flocculose, stuffed, ten to sixteen centimeters long, one to two centimeters thick; annulus ample, white or pale yellow, apical; volva large, membranous, tough, white, forming a wide, free cup with lobed or toothed margin.

Found in woods throughout the eastern United States, especially in Virginia and southward. It is said that the earlier Italian immigrants often confused this species with *Venenarius muscarius*, with fatal results. The expert would notice at once the large white volva, the yellow lamellæ, and the differently colored pileus; but my advice, even to experts, is to *avoid all species* of *Venenarius* when selecting fungi for food.

Pleuropus abortivus (Berk. & Curt.) Murrill. Edible. *Clitopilus abortivus* (Berk. & Curt.) Sacc. *Abortive Pleuropus.* (Fig. 2673.)—Pileus of developed form fleshy, firm, convex to nearly plane or slightly depressed, usually entire on the margin, gregarious or cespitose, five to ten centimeters broad, the sporophores very commonly represented by subglobose aborted masses of cellular tissue three to six centimeters in diameter; surface of developed form dry, silky-tomentose, becoming glabrous, gray or grayish-brown; context white, with farinaceous odor and taste; lamellæ adnate, close, thin, strongly decurrent, whitish or pale grayish, changing to salmon-colored; spores angular, unenucleate, salmon-colored, 8.5–10×6–7μ; stipe subequal, solid, slightly flocculose, longitudinally striate, concolorous or paler than the pileus, three and one-half to eight centimeters long, five to twelve millimeters thick.

Common on rich earth or much decayed wood in woods during late summer and autumn, from Canada to Alabama and west to Wisconsin and Mexico. It is very abundant about New York City, both in its fully developed and aborted forms, and I have seen the latter on sale in Mexican markets. The flavor is very poor, in my opinion, but some special method of cooking may be found to improve it. One must not confuse it with poisonous species of *Entoloma*, nor with the "eggs" of certain phalloids. Similar aborted forms are frequently found in *Armillaria mellea*, an edible species.

Two relatives of this species, unfortunately not common in this region, are considered delicious. The plum mushroom, *Pleuropus prunulus*, is five to ten centimeters broad, whitish or grayish above and

pinkish below, occurring in rich woods. The sweetbread mushroon, *Pleuropus orcella*, occurs in more open places, and is smaller and more irregular but with the same mealy odor and taste. None of the species of this genus, with pinkish, decurrent lamellæ, are known to be poisonous.

Pluteus cervinus (Schaeff.) Fries. Edible. *Fawn-colored Pluteus.*—Pileus rather thin and fragile, bell-shaped to expanded, six to ten centimeters broad; surface smooth or slightly radiate-fibrillose, avellaneous to subfuliginous, rarely white, sometimes streaked; context white, almost tasteless; lamellæ free, broad, white when young, becoming salmon-pink; spores broadly ellipsoid, smooth, flesh-colored, 6–8×5–6μ; cystidia ellipsoid, stout, thick-walled, hyaline, forked at the tip; stipe equal or enlarged at the base, white above, more like the cap below, usually glabrous, nearly solid, brittle, eight to fifteen centimeters long.

This species occurs quite commonly in open woods about stumps and on decaying wood of various kinds from June to November. It is of poor quality, and must be carefully distinguished from poisonous species of *Entoloma*.

Paxillus involutus (Batsch) Fries. Edible. *Involute Paxillus.*—Pileus convex to expanded or depressed, four to eight centimeters broad; surface variable in color, grayish, yellowish-brown, or reddish-brown, margin downy and inrolled when young; context yellowish, becoming brownish when bruised; lamellæ decurrent, reticulate on the stipe, pallid to greenish-yellow, changing to brown when bruised; spores ovoid, 7–9×4–5μ; stipe central or eccentric, short, equal, concolorous, three to five centimeters long, one to two centimeters thick.

This species is widely distributed, occurring in late summer and autumn on open ground or on dead logs and stumps in woods. In England and in Oregon, where the climate is moist, I have seen much larger specimens than in the eastern United States. Farther south, *Paxillus rhodoxanthus*, another excellent edible species, with tomentose, reddish-brown pileus and yellow lamellæ, is very common on clay banks along roadsides.

Inocybe infida (Peck) Earle. Poisonous. *Unsafe Inocybe.* (Plate P, Fig. 8.)—Pileus ovoid to campanulate, at length expanded, umbonate, gregarious, one and one-half to three centimeters broad; surface silky-scaly, shining, light tawny-brown, sometimes paler, dark reddish-brown on the umbo, often splitting at the margin; lamellæ free, crowded, pale yellowish to grayish-cinnamon; spores ovoid, irregular, nodulose, yellowish-brown, 10–11×6–7μ; stipe subequal, concolorous, pruinose, scurfy above, three to five centimeters long, two to four millimeters thick; veil white, evanescent, clinging in delicate threads to the stipe and the margin of the young pileus.

Fig. 2673.—Pleuropus abortivus.

This species occurs abundantly every summer and fall on the lawns of the New York Botanical Garden, and has been carefully studied. It is like *Venenarius muscarius* in its poisonous effects. *Inocybe infelix*, *Inocybe decipiens*, and *Inocybe rimosa* are also considered poisonous. These latter are mostly small, wood-loving plants, but *I. infida* grows where *Marasmius oreades* does and must be carefully avoided. Another lawn-loving species that might be picked by mistake is *Clitocybe sudorifica* Peck, apparently a poisonous variety of the common *Clitocybe dealbata*, which acts like a small quantity of *Venenarius muscarius*, causing profuse perspiration. It has been used to break up a cold.

Pholiota candicans (Bull.) Schroet. Edible. *Pholiota præcox* (Pers.) Quél. *Early Pholiota.*—Pileus fleshy, convex to plane, at times umbonate, solitary or gregarious, three to seven centimeters broad; surface smooth or pitted, glabrous, moist, whitish, cream-colored or isabelline, the center often darker; lamellæ adnexed, crowded, white, becoming fulvous; spores ellipsoid, smooth, ferruginous, 7–8×5μ; stipe subconcolorous, equal, glabrous, four to eight centimeters long, three to five millimeters thick;

veil large, white, forming a conspicuous and permanent annulus near the apex of the stipe.

This is one of our best edible species, and it occurs quite abundantly during spring and summer in grassy and open places throughout temperate regions. *Pholiota autumnalis*, recently found to be poisonous, occurs later in the season. Most of the ocher-spored gill-fungi that have been tested are harmless.

Hypholoma appendiculatum (Bull.) Quél. Edible. *Appendiculate Hypholoma.* (Plate XXXIV, Fig. 12)—Pileus fleshy, fragiel, thin, convex to expanded, cespitose or gregarious, two to six centimeters broad; surface glabrous or whitish-pulverulent, rarely floccose-scaly, usually cracking with age, hygrophanous, varying in color from pale-yellowish to light brown or dark honey-yellow, fading when old or dry; lamellæ adnate, close, narrow, white or creamy-white to purplish-brown; spores ovoid, smooth, purplish-brown, $7\times4\mu$; stipe slender, equal, hollow, white, glabrous below, pruinose at the apex, five to seven centimeters long, four to six millimeters thick; veil white, delicate, evanescent, clinging to the margin of young plants as shred-like appendages.

This is everywhere recognized as one of the best and most dainty edible species. It is very widely distributed and grows in abundance throughout the season about dead wood or in soil rich in decayed wood.

Hypholoma perplexum (Peck) Sacc. Edible. *Perplexing Hypholoma.* (Plate XXXIV, Fig. 11)—Pileus convex to nearly plane, cespitose, slightly umbonate at times, five to eight centimeters broad; surface smooth, glabrous, dry, latericeous to bay, the margin cream-colored to ochraceous; context usually of mild flavor, sometimes bitter, white or nearly so, becoming yellowish with age; lamellæ adnate, somewhat rounded, sometimes slightly greenish, and finally purplish-brown, $7–8\times4\mu$; stipe subequal, firm, hollow, slightly fibrillose, stramineous above, ochraceous or reddish below, six to ten centimeters long, five to seven millimeters thick, ornamented with an arachnoid annulus when young, which becomes conspicuous by reason of the spores which collect upon it.

This species occurs abundantly on stumps and roots of deciduous trees in autumn, appearing in conspicuous reddish clusters of considerable size. It is edible, but not very good in quality, being useful because of its late appearance. Peck separated it from *H. sublateritium* chiefly because it usually lacks the bitter taste ascribed to that species, of which it may be only a form. In collecting this species for food, young and fresh specimens of mild flavor should be selected, and they should be cooked for at least thirty minutes. Soaking in water with a little vinegar for twenty minutes before cooking improves the flavor.

Agaricus campester L. Edible. *Common Mushroom. Pasture Mushroom.* (Plate XXXIV, Fig. 1.)—Pileus convex to expanded, 5–9 cm. broad; surface dry, silky, and whitish or floccose-squamulose and light reddish-brown, the color being chiefly in the scales; context white, thick, solid, of mild flavor, sometimes becoming reddish when broken; lamellæ free, rounded behind, ventricose, crowded, white when young, becoming salmon-pink, and finally brown or blackish; spores ellipsoid, smooth, dark brown, $10–12\mu$ long; annulus delicate, inconspicuous, formed from a thin, white veil, which covers the lamellæ in their younger stages; stipe smooth, white, cylindric, nearly equal, stuffed within, three to six centimeters long, one and one-half to two centimeters thick.

The common mushroom occurs in low grass on meadows or on rich, moist, upland pastures, being common after rains from August to October in this latitude. The "spawn," or vegetative portion, is hidden in the soil and feeds upon the dead organic matter found therein. In the cultivation of this species, bricks of spawn are planted in suitable soil and the conditions of growth attended to with great care. This is the mushroom usually found in market, either in the fresh stage or in cans. Most persons who collect fungi for food in the fields limit themselves to this one species.

Agaricus placomyces (Peck). Edible. *Flat-cap Mushroom.*—Pileus rather thin, convex to plane, solitary, five to twelve centimeters broad; surface whitish or grayish, adorned with small brown scales, darker at the center and usually becoming brownish over the whole surface with age; lamellæ white, then pink, and finally blackish-brown; spores brown, $5–8\times3–4\mu$; stipe long, slender, whitish or slightly yellowish, bulbous at the base, five to ten centimeters long, five to seven millimeters thick; annulus superior, somewhat double and radially cleft.

This species resembles the common pasture mushroom, but has a longer stipe and grows in thin woods or wood borders. It is excellent, but unfortunately not common.

Agaricus arvensis Schaeff. Edible. *Horse Mushroom. Field Mushroom.* (Fig. 2674.)—Pileus large, convex, six to fifteen centimeters broad; surface white,

Fig. 2674.—Agaricus arvensis.

becoming yellowish with age or on drying; context white, thick, highly flavored, and easily digested; lamellæ white to pale pinkish at first, at length brown; stipe long, white, often enlarged at the base, five to ten centimeters long, eight to sixteen millimeters thick; annulus of two parts, membranous and white above, radiately split and tinged with yellow below.

This species grows in rich soil in pastures, fields, and wood borders from midsummer to early fall. It resembles the common mushroom, but is larger, with longer stipe, paler lamellæ, and a peculiar double annulus. I have often eaten it in Sweden and found it delicious. A slender wood-loving edible species, *Agaricus silvicola*, can hardly be distinguished from it.

Coprinus.—The "ink-caps" are abundant and excellent, and it is almost impossible to confuse them with poisonous species on account of the peculiar way they have of melting into a black fluid when mature. The three species here described would constitute an important addition to our food supply if more generally used. They are very tender and very digestible, but are perishable and should be cooked promptly.

Coprinus micaceus (Bull.) Fries. Edible. *Glistening Ink-cap.* (Plate XXXIV, Fig. 7.)—Pileus thin, ovoid to campanulate, cespitose, one and one-half to two and one-half centimeters in diameter, soon expanding and becoming discolored; surface striate, tawny-yellow or tan, yellowish-orange on the umbo, usually covered with minute, glistening scales when young; context thin, white, of nutty flavor, quickly deliquescing in wet weather; lamellæ white when young, soon becoming purplish-brown and finally black; spores ellipsoid, dark brown, 6–7μ, stipe white, slender, fragile, hollow, three to ten centimeters long.

The glistening ink-cap grows abundantly in dense clusters about stumps and dead trunks, especially of elm, and appears very early in the season, developing after rains from April to November. It is of small size, but delicate in flavor and easily prepared in a variety of ways. The plants should be gathered young and cooked within a few hours.

Coprinus atramentarius (Bull.) Fries. Edible. *Common Ink-cap.* (Fig. 2675.)—Pileus ovoid to campanulate, finally expanding and deliquescing, densely cespitose, three to six centimeters broad; surface glabrous or slightly scaly, especially on the disc, grayish or brownish, often with a yellowish tint, blackening with age; context white, quickly deliquescing; lamellæ crowded, white when young, soon becoming black and dissolving; spores ellipsoid, black, 7–10μ; annulus sometimes apparent near the base of the stipe as an indistinct line; stipe slender, smooth, white, hollow, five to ten centimeters long.

Fig. 2675.—Coprinus atramentarius.

This excellent, edible species is quite common in rich soil on lawns and elsewhere during late summer and autumn. As it appears in close clusters, it may usually be obtained in greater abundance than the shaggy-mane. Owing to its deliquescent character, it must be cooked very soon after it is collected.

Coprinus comatus (Muell.) Fries. Edible. *Shaggy-mane. Maned Agaric. Horsetail.* (Fig. 2676.)—Pileus at first oblong, subcylindric, expanding and deliquescing with age, four to six centimeters in diameter; surface shaggy, white, with yellowish or brownish scales, tinged with lilac in places, grayish-black on the margin, blackening with age; context white, tender, of nutty flavor; lamellæ crowded, white when young, soon changing to pink, then to black, and finally melting away into an inky fluid; spores ellipsoid, black, 13–16μ; annulus white, small, movable or slightly adhering, often falling away at an early stage; stipe slender, smooth, white, hollow, seven to twelve centimeters long.

Fig. 2676.—Coprinus comatus.

The shaggy-mane is a very conspicuous object on lawns in autumn, although it is not always so abundant as might be desired. On account of its peculiar shape and decided colors, a single specimen rarely fails to attract attention. It is considered one of the very best and most digestible of the fungi, and is often eaten raw by foreigners. At times, this species occurs in enormous quantities in rich, loose earth by roadsides or in weedy places, and it then becomes an important source of food supply. It requires little cooking, and is best broiled and seasoned simply.

Puffballs.—Puffballs are the safest of all fungi for the beginner in mycophagy, none of them being poisonous; and they are at the same time excellent and easy to obtain. Being tender, they cook quickly and are easily digested. They should as a rule be cut open before cooking to see that they are not too old and that they are really puffballs. If they are white and firm like cream cheese inside, showing no yellow or brownish discoloration, they are of the right age to use. If the interior shows no special structures, but is smooth and homogeneous, then one may be sure he has a puffball. The "egg" of the deadly amanita contains the young cap and stem inside, which is readily seen when the egg is cut; and the "egg" of the stinkhorn shows the stem and a green mass inside surrounded by a layer of jelly-like substance.

Puffballs may be cooked alone in various ways, or used in stews, omelets, and for stuffing roast fowls. When used in omelets, they should be stewed first. All kinds except the very small ones should first be peeled and cut into slices or cubes, after which they may be fried quickly in butter, or dipped in beaten egg and fried like egg-plant, or cooked in any of the ways recommended for the ordinary mushroom. The smaller kinds are much inferior in flavor to the larger ones and need a few specimens of some good mushroom to make them attractive.

Lycoperdon gemmatum Batsch. Edible. *Studded Puffball.* (Fig. 2377.)—Peridium turbinate, subum-

bonate, usually whitish or gray, two to four centimeters in diameter, narrowed below into a short, stem-like base; cortex of long, erect spines or warts of irregular shape scattered among small granular and more persistent ones, all of which finally fall away, leaving the surface reticulated with fine dotted lines; capillitium and spores greenish-yellow, at length pale brown, columella present; spores globose, smooth or slightly roughened, about 4μ in diameter.

Fig. 2677—Lycoperdon gemmatum.

This is a very common species, growing usually on the ground in woods. Although extremely variable, it is recognized without much difficulty by the character of its spiny covering, the larger spines somewhat resembling the shape of cut gems. The plants generally grow near together and are occasionally cespitose, but are rarely so crowded as in the case of the pear-shaped puffball, *Lycoperdon pyriforme*, a small species of poor quality occurring in great abundance on decaying wood or sawdust.

Lycoperdon cyathiforme Bosc. Edible. *Large Field Puffball. Common Pasture Puffball.* (Fig. 2678.)—

Fig. 2678.—Lycoperdon cyathiforme.

Peridium large, subglobose to turbinate, five to fifteen centimeters in diameter, the base short and thick; surface smooth, glabrous or finely floccose, whitish-gray or brown, becoming purplish and rimose-areolate above with age, cuticle thin, easily separating; capillitium and spores purplish-brown, falling away in age with the upper part of the peridium, leaving a persistent cup-shaped base with a ragged margin; spores sessile, globose, distinctly echinulate, purplish-brown, 5–7μ in diameter.

This puffball occurs commonly in the eastern United States in meadows and pastures where the common mushroom may be expected to grow, but its excellent qualities appear to be unknown to most persons. It is the largest puffball in this region except the giant puffball, which is much rarer. Bosc originally described it from the cup-shaped sterile base, hence the specific name is hardly appropriate. It sometimes grows in circles, and it has been known to be so abundant as to seriously injure lawns.

The giant puffball, *Lycoperdon giganteum*, may be readily recognized by its large size, usually about the size of a man's head, and its smooth, white appearance. It occurs infrequently in fields, pastures, or woods throughout most of the United States.

Scleroderma aurantium (L.) Pers. Inedible. *Common Scleroderma. Hard-skinned Puffball.*—Peridium depressed-globose, subsessile, radicate, often cespitose, two and one-half to eight centimeters in diameter, thick, corky, usually pale with yellow shades, or orange, sometimes brown, mostly covered with large warts; gleba at first white, then vinaceous to bluish-black, finally greenish-gray, lines of trama whitish; spores dark, globose, warted, 7–12μ.

A very common and widely distributed species growing in dry woods, especially under chestnut trees. I have eaten the young sporophores, but do not consider them attractive. Persons have brought them to me thinking they were truffles. This and related species were formerly considered poisonous but are now believed to be harmless, although not desirable for food. They may be readily distinguished from the true puffballs by their black interior and hard skin.

Phalloids.—Remarkably little is definitely known regarding the properties of the phalloids, the only suspected group of the Gasteromycetes. It seems that the strong and disagreeable odor of many of these plants has discouraged experimentation in this line, and certainly no one would use them for food unless by mistake. *Phallus impudicus, Dictyophora duplicata, Clathrus cancellatus*, and other species have been usually considered poisonous. MacIlvaine has tested the "eggs" of a few species and considers them harmless, while mature specimens are said to be uniformly fatal to swine. If the "eggs" of all species should be found to be harmless, the danger of confusing puffballs with poisonous fungi would be re-

duced to distinguishing the undeveloped stages of species of *Venenarius*, which on sectioning show the tiny pileus and stipe within the membranous wrapper.

Dictyophora duplicata (Bosc) Ed. Fisch. Considered Poisonous. *Veiled Stinkhorn.* (Fig. 2679.)—Pileus campanulate, five centimeters long, the surface appearing strongly reticulate-pitted after the fetid, olivaceous gleba has been devoured by flies or washed

Fig. 2679.—Dictyophora duplicata.

away by rains; apex truncate, perforate; spores oblong-ellipsoid, $4 \times 2\mu$, involved in mucus at maturity; stipe fusiform-cylindric, tapering at each end, cellular-spongy, white, hollow, ten to twenty centimeters high, two and one-half to three centimeters thick; veil white, reticulate, variable in length, sometimes much expanded, always conspicuous, fragile; volva globose, nearly white, very poisonous, five to seven centimeters in diameter.

This very conspicuous and objectionable species occurs in the United States about buildings and near stumps in fields and in the edges of woods. It may be easily recognized by its conspicuous veil, which is attached near the apex beneath the pileus and hangs down to the middle of the stipe or lower. The mature gleba is extremely fetid, proving attractive to flies, which probably disseminate the spores. A similar species, *D. ravenelii*, possessing similar properties, occurs in abundance in old sawdust piles and about rotting logs and stumps in woods and fields in the eastern United States and Canada. It may be readily distinguished from the veiled stinkhorn by the absence of a conspicuous, reticulate veil; its cap is also smooth instead of coarsely pitted, and its odor is less penetrating and disagreeable.

Glossary.

Adnate, attached squarely to the stipe.
Adnexed, attached slightly to the stipe.
Annulus, the ring or collar on the stipe.
Appendiculate, hanging in small fragments to the margin.
Avellaneous, drab.
Bulbous, with a bulb-like swelling at the base.
Cespitose, clustered.
Circumscissile, splitting transversely at the middle.
Context, the substance of the pileus.
Decurrent, extending downward on the stipe.
Dimidiate, semicircular or nearly so.
Disc, the central part of the surface of the pileus.
Distant, said of lamellæ when they are far apart.
Eccentric, not centrally attached.
Echinulate, minutely spiny.
Equal, said of the stipe when of uniform thickness.
Floccose, clothed with hairs.
Free, not attached to or not reaching the stipe.
Fuliginous, sooty or dark brown.
Fulvous, tawny.
Fumosus, smoky.
Furfuraceous, clothed with numerous minute scales.
Glabrous, devoid of hairs or scales.
Gleba, the spore-bearing tissue of puffballs and their allies.
Gregarious, growing in groups.
Hygrophanous, as though water-soaked.
Hymenium, the fruiting surface or layer.
Hymenophore, the fruit-body.
Imbricate, overlapping like tiles on a roof.
Involute, rolled inward.
Isabelline, light leather-colored.
Lamellæ, the gills of a mushroom.
Latericeous, brick-colored.
Luteous, egg-yellow.
Melleous, honey-yellow.
Miniatous, scarlet.
Murinous, mouse-colored.
Mycelium, the vegetative part of a fungus, made up of delicate threads.
Ochraceous, ocher-yellow.
Ochroleucous, yellowish-white.
Ocreate, fitting like a stocking or boot.
Peridium, the wall of puffballs.
Pileus, the cap of a mushroom.
Pulverulent, covered with powder or dust.
Reticulate, net-like or marked with net-like lines.
Sinuate, notched where they join the stipe.
Sporophore, the fruit-body, or part bearing the spores.
Squamose, scaly.
Stipe, the stem.
Superior, said of the annulus when near the apex of the stipe.
Testaceous, pale brick-colored.
Tomentose, clothed with dense, matted hairs.
Umbilicate, slightly and abruptly depressed at the center.
Umbo, an elevation at the center of the pileus.
Veil, a membrane at first covering the gills, at length forming the ring.
Ventricose, enlarged at the middle.
Virgate, streaked.
Volva, a membrane covering the entire fruit-body when young, at length forming a cup at the base of the stipe or distributed in fragments over the surface of the pileus or stipe.

William A. Murrill.

Fungous Foot.—See *Mycetoma*.

Fungus Chirurgorum.—Spunk.—*Surgeons' Agaric, Touchwood.* The prepared tissue of *Polyporus fomentarius* or of *P. igniarius* Fries (fam. *Agaricineæ*). These are rather large species of fungi, parasitic upon the trunks of forest trees, especially of oaks and beeches. They are attached by broad bases and expand horizontally in large, roundish, hoof-shaped masses of corky texture and reddish or grayish-brown color. The upper surface is convex and marked by a series of distinct concentric rings, each indicating a year's growth. The under side is flat. The first-named species is said to yield the best product. The fungus has its upper and lower surface trimmed off, is softened in water, beaten with a wooden mallet into a tough, soft, and flexible buck-skin-like sheet, and dried. In this condition it will absorb more than twice its weight of water. The uses of spunk are purely surgical. Before the days

of modern styptic and absorbent appliances, it was largely depended upon for checking hemorrhage, through its mechanical properties, as lint and similar substances are now used. Its softness and flexibility also adapted it well to use for padding purposes. In this country its use has almost entirely ceased.

Soaked in a solution of niter or chlorate of potassium, it becomes very inflammable, and such a preparation was enormously used as tinder before the days of matches. W. P. Bolles.

Funiculitis, Endemic,—A name given by Castellani to a suppurative phlebitis or cellulitis of the spermatic cord which is observed with some frequency in Ceylon and elsewhere in the tropics.

There is an infection, generally with diplococci or streptococci, no single bacterium having been identified as specially causative. The manner of infection is unknown. The whole cord is inflamed, infiltrated and much swollen. The epididymis is often involved, the testicle proper very seldom. The disease is usually unilateral.

The onset is sudden and the patient is apt to attribute it to some slight injury or overexertion, or chilling. The disease is dangerous and often fatal within a few days, if not relieved promptly by extensive free incisions and open dressing. It is sometimes necessary to extend the incisions as far as the internal ring, and orchiotomy or orchidectomy may be required.

In two untreated and rapidly fatal cases which came to autopsy during the writer's service in the Canal Zone, suppuration of testicles and cords on both sides, and of the inguinal and retroperitoneal glands had occurred, and the cases bore a considerable postmortem resemblance to bubonic plague. In one of these cases the pus showed only the pneumococcus in pure culture; the lungs showed no involvement. J. F. Leys.

Furfurol.— This substance occurs as the constituent of many vegetable oils and is formed in the distillation or heating of most carbohydrates and glucosides. It may be formed also in the cleavage of different animal nucleic acids and from glycuronic acid. It is strongly toxic for man, acting principally upon the central nervous system. It is a colorless easily volatile fluid with an odor resembling oil of bitter almonds. The boiling point is 161° C. F. P. U.

Furuncle.—See *Boil.*

Gad-flies.—*Tabanida*, a family of biting flies. These insects are distributed widely over the world. They are in the habit of coming to the water to drink and hence may be killed by sprinkling the water with kerosene. The eggs are attached to aquatic plants and the larvæ live in the water or in damp earth. It is possible that these flies disseminate trypanosomes, *Filaria*, and other parasites. See *Insects, parasitic.* A. S. P.

Gairdner, Sir William Tennant.—Born in Edinburgh, Scotland, November 8, 1824. He received the degree of Doctor of Medicine from the university of that city in 1845, and soon afterward began the practice of his profession. In 1853 he accepted a call to fill the Chair of Medicine in Glasgow. After the death of Laycock he was chosen Physician-in-Ordinary to the Queen. In 1898 he was made a K. C. B. (Knight Commander of the Bath). He died in 1907.

Of his published writings the following deserve to receive special mention: "On the Function of Articulate Speech, and on its Connection with the Mind and the Bodily Organs," Glasgow, 1866; "The Glasgow Health Lectures," 1877–1881; "Medical Education, Character, and Conducted," Glasgow, 1883; and The " Physician as Naturalist, " 1889. A. H. B.

Galactagogues.—(Gr. γάλα, milk, and ἄγειν, to lead.) The section of milk is normally associated with pregnancy, but may occur in pseudocyesis, and in ovarian and uterine tumors. It is often seen during the first week of life, in both male and female children. The secretion of milk may be established and maintained by the application of a nursing child to the breast of a woman who is not at the time and never has been pregnant. In one case a child eight years old nursed her mother's infant for some months, and in another a woman fifty-nine years old, ten years after the cessation of menstruation, nursed a child for some time.

The length of time during which the milk may continue to be secreted varies from nine to sixteen months, but in rare cases this period may be prolonged for as long a time as five years, if the child be allowed to nurse.

The causes of defective lactation are various in character. Thus, for example, there may be some mechanical interference with the escape of the milk, as when the lactiferous tubes and acini are not developed, or the epithelial cells are imperfect, or a previous injury or disease has caused total destruction of the glandular tissue. These conditions are not amenable to treatment. On the other hand, when there is simply a lack of development, or the gland and nipple have received some trifling injury, the condition should be investigated and treated before the end of gestation. The breast of every pregnant woman should be examined by her physician three or four months before the expected confinement, and if the breasts are found to be small and poorly developed and the nipples fissured or depressed, appropriate treatment should be instituted. If the nipples are hard, the application of some bland aseptic oil or ointment—*e.g.* castor oil or castor oil and subnitrate of bismuth, lanolin and boric acid—will be found useful as a means of softening them. The breast should be massaged, and at the same time the nipples should be drawn out by grasping them between the thumb and finger, while with the other hand the breast is stroked toward the nipple. This should be done daily for five or ten minutes at a time. The adoption of these measures will enable the child, when placed at the breast—which should be done as soon after labor as the mother's strength will permit—to grasp the nipple effectively. After this first attempt at nursing, the child should be placed at each breast, alternately, every four hours. Should the child be unable to grasp the nipple, the latter should be drawn out with the breast pump or a clay pipe, and, if this does not prove sufficient, a glass nipple shield, with rubber nipple, should be employed. The sucking of the child is the best stimulus to the flow of milk, and should always be obtained if possible; but, if the child cannot be made to nurse, then suction will have to be made with the breast pump for five or ten minutes every four hours. The breast at the birth of the child contains colostrum, and at the end of from thirty-six to sixty hours ripe milk. During the first period the child should be nursed every four hours, but afterward, on the appearance of ripe milk, it should be nursed every two to three hours.

Another cause of defective lactation is a plethoric state of the body, a condition which readily responds to treatment. The diet should be carefully regulated, milk being made one of its chief constituents, and all stimulants should be avoided. The extract of thyroid gland should also be prescribed in one to five-grain

doses, three times a day. Under this plan of treatment, combined with the occasional administration of a dose of castor oil, the obstruction to the flow of milk should soon disappear. In these cases the use of the thyroid gland extract not only increases the flow of milk, but at the same time improves its nutritive quality.

Torpor of the mammæ is another cause of inactivity of their secretory apparatus, and when this is the case great benefit may be derived from the application of electricity. Both poles having been moistened, the positive one is placed deep in the axilla or on the back, while the negative one is applied gently over the nipple. The current employed should be no stronger than is agreeable to the patient, and this mode of applying it should be continued for about two minutes. Afterward, the negative pole should be glided along the sides of the breast, in a stroking fashion, for another two minutes. Then, finally, the poles should be applied to the sides of the breast for the same length of time. Electricity may be applied in this manner once a day for a period of four or five days; and usually it will be found that a single such séance will fill the breasts after the milk has disappeared for some days.

Among the other local therapeutic methods which have been used with varying success may be mentioned the application of warm poultices made of a weak mixture of mustard (not strong enough to burn) or of calabar bean, or of the leaves of the castor-oil plant. Gentle massage alone will often suffice to start the flow, or we may combine with it inunction of olive oil or of castor oil. Repeated applications of the breast pump and enveloping the breast with warm cloths are also very efficient methods.

The internal administration of drugs, for their galactagogue action, has not proved very satisfactory. Pituitrin given intravenously or subcutaneously in doses of 1 c.c. of a solution containing 0.1 gram of the posterior lobe of the hypophysis will increase the flow of milk in a few minutes. This is caused by a rise in the general blood pressure (due to the contraction of peripheral arterioles) and the contraction of the muscle fiber of the breast. Its continued use will diminish the flow of milk as less blood will be supplied to the breast under its action. The quantity of milk does not seem to be affected. Jaborandi will, it is true, increase the flow of milk, but its action is only temporary and cannot be depended upon when a prolonged effect is needed. It is best given in the form of the fluid extract of pilocarpus, in half-dram doses; this preparation being less nauseating then the jaborandi itself. Or the effects of the drug may be obtained from hypodermatic injections of pilocarpine hydrochlorate, in gr. $\frac{1}{12}$ doses.

Physostigmine increases temporarily the flow of milk. So also do the preparations of ammonia—the carbonate and the acetate—when given in moderately large and continued doses. The alcoholic stimulants, such as ale, porter, and beer, and the malt preparations possess the power of increasing the quantity of milk secreted, but the quality is thereby deteriorated. To such a degree is this true that they should rarely be used except in small quantities. Lactagol, an extract of the grains of cotton seed, seem to increase the flow of milk and improve the quality by increasing fats and casein. The volatile oils, especially the oil of anise, impart a pleasant flavor to the milk, and in consequence the child will be likely to draw much better. In this indirect manner they may serve to increase the flow of milk.

The most usual cause of defective lactation is anemia. It is a well-known fact that the functional activity of an organ is directly proportional to the supply of blood furnished to that organ, and this is a very important law to remember when we are dealing with such a gland as the mammary. We may therefore expect to secure the greatest improvement in the secretion of milk from the taking of those substances and the adoption of those hygienic measures which tend to increase the supply of blood and to improve its nutritious qualities. The mother should be in the best possible condition before and after the arrival of the child, and this result should be secured by the administration of tonics, such as iron, arsenic, nux vomica, and quinine, and by the patient's taking proper food and exercise. The diet suitable for a nursing mother should be nutritious and easily digested. For the first few days of the puerperal period the mother should have milk, animal teas and broths, eggs, gruel, soups of beans and peas, and small amounts of tea, cocoa, or coffee, with toast and crackers. It is well to avoid the limited diet of tea and toast which so many women take at this time. Later on in this period and during that of lactation, the mother should have an abundant supply of water, soups, meats, milk, eggs, and vegetables. Of the latter, turnips, carrots, beets, potatoes, spinach, asparagus, and lettuce will aid in the formation of milk. The mothers of the working class will be found to give milk in larger quantity and of a better quality than do those who live under higher social conditions. This is due to their simple mode of living and to their outdoor life.

Systematic exercise in the open air should be taken as soon after confinement as the mother's condition will permit, for by this means the proteids will be diminished in amount and the fat increased, thus creating a milk which is easily digested by the child.

The mother should at the same time avoid those drugs which decrease the milk supply, namely, belladonna, when taken in large amounts or used locally, and saline and hydragogue purgatives; for the removal of large amounts of fluid from the body will greatly diminish the supply of milk. It is also desirable to prevent, as far as possible, any nervous shock or worriment, for the effect upon the mother is likely to be such that her milk will be rendered unfit or the child.

The proper care of the breast during lactation is important. The nipple and breast should be washed with a saturated solution of boric acid both before and after nursing, and these parts should be kept covered with soft sterile lint or gauze held in place by a breast binder which gives support and ease to the breast. If this course is adopted there will be fewer cracked nipples and abscesses of the breast. In cases in which fever occurs during lactation it is often possible to retain the secretion of milk for three or four weeks, if the breasts are gently massaged and emptied three or four times a day with the breast pump. Then, when the temperature returns to normal, the child may again be put to the breast. In those cases in which there has been an abscess of the breast in early infancy, or during a former lactation, the danger of the formation of a fresh abscess is only slightly greater than it is in a perfectly normal breast. If care is taken to keep the parts thoroughly clean, and if they are not allowed to become engorged, we may rightly expect that such a breast will furnish a sufficient supply of good milk.

STRICKER COLES.

Galactose.—$C_6H_{12}O_6$. This is a monosaccharide sugar obtained from the hydrolytic cleavage of milk-sugar and by hydrolysis of many other carbohydrates, especially various gums and mucilages. It is also formed from cerebrin, a nitrogenous glucoside-like body prepared from brain tissue, by treating with dilute mineral acids. F. P. U.

Galanga; Galangal.—Lesser Galangal. The rhizome of *Alpinia officinarum* Hance (fam. *Zingiberaceæ*), a perennial herb of flag-like habit and the floral peculiarities of ginger and cardamom plants. It is an

inhabitant of Hainan and other parts of Southern China, where it is also cultivated as an article of commerce. Galanga has been long known in Europe, as well as in Asia, and was formerly esteemed as a domestic spice or flavor.

The dried rhizome is cylindrical, often branched, about as large as the little finger, and in pieces two or three inches in length. The nodes are close together and very prominent, as slender annulations. Texture hard, tough; color deep brown; odor aromatic, curcuma-like; taste pungent. It contains an *essential oil* to which its odor is due, and probably some pungent resin. The oil is reddish-yellow, with the odor of cajeput and the taste of camphor. It has a specific gravity of 0.921, and contains cineol. Its qualities as a medicine are essentially those of ginger. As a medicine galanga is obsolete in Europe, and nearly so as a spice, although it is said to be used with other things in flavoring cordials, in veterinary mixtures, etc.

HENRY H. RUSBY.

Galbanum.—"A gum-resin obtained from *Ferulo galbaniflua* Boiss. et Buhse (fam. *Umbelliferæ*), and probably from other species" of *Ferula* (B. P.; no longer official in the United States). It is not certain whether the product of the "other species" always comes separately, as it certainly sometimes does, or whether the drug is sometimes a mixed product. The plants are huge perennial herbs of Persia and the adjacent region.

The galbanum exists, like other gum resins, in the plant as a fragrant creamy latex, and exudes spontaneously from the crown and stem, or flows upon puncture, in white drops that soon become thick and sticky, and finally hard and brittle, by the action of the air. As they dry, they also turn to a light yellow-brown or buff color. These drops or tears, collected when nearly dry and not sticking together, compose the "Galbanum in tears"; when collected in a softer state, and running more or less completely into a granular or even homogeneous mass, they are the more common "galbanum in mass." The pharmacopœial description was as follows: "In tears from the size of a pin's head to that of a pea, and larger; mostly agglutinated, forming a more or less hard mass; externally yellowish, or pale brown; internally milk-white, bluish-white, or yellowish, with a waxy luster; odor peculiar, balsamic; taste bitter and acrid. When moistened with alcohol, galbanum acquires a purple color on the addition of a little hydrochloric acid."

Like other substances of its class, galbanum makes a yellowish emulsion with water, and contains a varying amount of *essential oil* (six per cent., more or less) according to its freshness and softness. It consists, besides, of about three-fourths *resin* and one-fourth *gum*, excluding a variable amount of coarse impurities. The oil is a colorless, pleasant-smelling hydrocarbon of the turpentine type. It is an article of commerce, and described by Schimmel as having a normal specific gravity of 0.930, boiling between 165° and 300° C., and containing *cadinene*. The resin is a yellowish-white amorphous substance, soluble in alcohol, and remarkable for yielding by dry distillation a brilliant *blue*, rather thick *essential oil* (see German Chamomile for similar substance), and the crystalline substance called *Umbelliferon*, which, in its turn, melted with potash, yields the derivative *resorcin*.

Galbanum was used by the ancient Hebrews as an ingredient of some incenses. Along with other gum resins it has had, in its day, some reputation as an emmenagogue and antispasmodic, and it is still occasionally given with these qualities in view. Somewhat more often it is administered in chronic bronchitis or laryngitis as an expectorant. Rarely it is given in rheumatism, with probably no benefit. The principal present employment of this antiquated medicine is as an ingredient of stimulating plasters.

It should be heated and strained, to separate dirt and refuse, before employment in pharmacy. A full dose is gr. x.–xx. (0.6–1.2), which can be administered in pill form or as an emulsion.

HENRY H. RUSBY

Galbraith Springs.—Hawkins County, Tennessee.

POST-OFFICE.—Galbraith Springs. Hotel and cottages.

ACCESS.—Via Southern Railroad to Russellville, Hamblen County, thence 9 miles north by private conveyance to Springs. Motorists from Knoxville, Chattanooga and other points south will find an easy route to Galbraith Springs viâ Jefferson City, Morristown, Russellville, and Red Bridge Ferry.

For the last three-fourths of a century these Springs have been known and resorted to by the inhabitants of the surrounding districts. In *ante-bellum* days they were frequented by hundreds, who made their temporary abodes in pole cabins around the Springs. The location is in a broken, mountainous country, 1,400 feet above the sea-level. The immediate surroundings of the Springs are uniquely charming in their wealth of vale and wood, brooks, rivulets, and waterfalls, and other features to please the fancy. The situation of the Springs is one mile distant from the Holston River, in a romantic glen, 330 feet above the base of Short Mountain. A path leads to the United States Signal Station on the top of Short Mountain, which is 1,302 feet above the Springs and 2,702 feet above the sea-level. From this point one of the most extended and charming views to be found among the mountains of East Tennessee is revealed to the eye. The hotel is a very comfortable establishment, where the visitor will soon learn that all the needful arrangements for his comfort and diversion are at hand. Among the amusements at Galbraith Springs may be mentioned bowling, dancing, and music. Hunting and fishing may also be indulged in. The springs are four in number. An analysis of Galbraith chalybeate water was made in 1884 by Prof. W. A. Noyes, of the University of Tennessee, with the following results:

LIGHT CALCIC-CHALYBEATE.

ONE UNITED STATES GALLON CONTAINS:

Solids.	Grains.
Calcium carbonate	3.84
Calcium sulphate	.92
Calcium nitrate	Trace.
Calcium phosphate	Trace
Magnesium carbonate	.47
Lithium carbonate	Trace.
Sodium sulphate	.26
Sodium chloride	.07
Potassium sulphate	.16
Iron carbonate	.41
Alumina	.03
Silica	.68
Total	6.84

Temperature of water, 55° F.

This analysis shows a very light mineralization, yet the water seems to possess considerable merit as a ferruginous tonic, and can be taken in large quantities. It is also an excellent table water.

The spring at Mooresburg near Galbraith's Springs is the source of Galbraith's Epsom Lithia Water considered to have excellent medicinal qualities. The following analysis was made in 1903 by Prof. Charles A. Mooers, chief chemist of the University of Tennessee:

Magnesia	72.730
Lime	44.422
Soda	3.550
Potash	5.649
Silica	1.890
Chlorine	1.566
Sulphuric acid	180.110
Carbonic acid	19.514
Lithia	Trace.
Total grains per gallon	329.431

The combinations may be made as follows:

Magnesium sulphate	217.303
Calcium sulphate	47.474
Potassium sulphate	10.451
Sodium sulphate	4.988
Sodium chloride	2.584
Calcium carbonate	44.387
Silica	1.890
Lithia	Trace.
Total grains per gallon	329.077

This is an unusually rich Epsom Water. It is free from organic matter and is thoroughly wholesome and well adapted to medicinal purposes. Taken in small doses it is a gentle laxative. Taken in large doses it is a purgative. It has also a tonic and alterative action. These waters are used in the treatment of the diseases of the stomach, liver, kidneys, bowels, diseases of women, in scrofula, rheumatism, gout, malaria, and in skin diseases.

EMMA E. WALKER.

Gale, Thomas.—Born in England in 1507. He studied medicine under Richard Ferris, who afterward became Queen Elizabeth's physician. Gale was one of Henry the Eighth's surgeons at the battle of Montreuil, in 1544; and thirteen years later (1557) he served in the same capacity under Philip II., King of Spain, at the battle of St. Quentin. The date of his death is not known. He was still living, however, as late as 1586. He shared with Richard Wiseman the honor of bearing the surname of the Ambroise Paré of England. His most important published writing bears the following title: "An Enchiridion of Chirurgerie," etc., London, 1563. A. H. B.

Galenus, Claudius.—Born about 130 A. D. in Pergamos, a city of Asia Minor. He began the study of medicine at the age of seventeen. When he reached

FIG. 2680.—Claudius Galenus.

his thirty-third year he visited Rome and remained in practice in that city for four or five years. Although he had been very fortunate in his surgical work at home, in Pergamos, he confined himself in Rome strictly to the practice of medicine. Among his notable successes he cured the Emperor Marcus Aurelius of a stomach disorder which he contracted during the campaign in Germany. Galen died in Rome at the age of seventy, during the reign of Septimus Severus, in the year 201.

Over five hundred treatises on a great variety of topics (in the domains of medicine, philosophy, grammar, and geometry) were attributed to Galen's pen, but very many of them were destroyed in the fire which consumed the Temple of Peace in Rome. Nevertheless, many of his writings have come down to our time. Galen's system of medicine reigned despotically over the civilized world for more than thirteen centuries. For a description of the outlines of this system the reader is referred to the article, on the History of Medicine in a later volume of this HANDBOOK. According to Withington, his chief physiological work was in relation to the nervous system. "He distinguished sensory, motor, and mixed nerve trunks, traced the connection between the vagus and the sympathetic, showed the importance of the recurrent nerves for the production of voice, and above all pointed out that the nerves have no power in themselves but merely conduct impulses to and from the brain and spinal cord." He classified the muscles according to their functions as flexors, extensors, etc., he refuted the doctrine held at that time that the arteries contain air, showing that they were filled with blood, and he asserted that the heart was a muscle, although he does not appear to have had any notion of the circulation of the blood.

From the long list of published writings which may unquestionably be attributed to Galen, the following four or five may be selected as of special importance: "De anatomicis administrationibus libri IX., Paris, 1531; "De nervorum dissectione," Paris, 1526; "De usu partium corporis humani libri XVII.," Basel, 1531; "De locis adfectis libri sex," Paris, 1513; and "Ars medica," Venice, 1483. A. H. B.

Gall, Franz Joseph.—Born March 9, 1758, in Tiefenbrunn, Duchy of Baden, Germany. He studied medicine at Strasbourg and received the degree of Doctor of Medicine in Vienna, in 1785. He began the practice of his profession in the latter city, but his predilection for the philosophy of medicine soon led to his giving a great deal of thought to the subject of cranioscopy and intellectual physiology. As soon as he began to promulgate his views on this subject the Austrian Government took alarm and forbade his further

FIG. 2681.—Franz Joseph Gall.

lecturing. On April 3, 1805, he held in Berlin, before an audience of 500 persons, the first of a series of séances on phrenology. The course proved extremely popular. In 1807, after lecturing in nearly all the important cities of Europe, he settled permanently in

Paris. His death occurred at Montrouge near Paris, August 22, 1828.

For an exposition of the peculiar views held by Gall the reader is referred to the following published work, in four volumes, the first two of which were written by Gall and Spurzheim conjointly: "Anatomie et physiologie du système nerveux en général, et du cerveau en particulier, avec des observations sur la possibilité de reconnaître plusieurs dispositions intellectuelles et morales de l'homme et des animaux, par la configuration de leurs têtes, Paris, 1810–1820.

A. H. B.

Galla.—Nutgall.—*Galls; Gallæ; Galla halapensis; G. Turcica; G. levantica; G. tinctoria; G. quercina.* Excrescences on *Quercus lusitanica* Lam. (*Q. infectoria;* Olivier, fam. *Fagaceæ*), caused by the punctures and deposited ova of *Cynips* (*Diplolepia,* Latreille) *Gallæ tinctoriæ,* Olivier.

The species of oak here named is very variable and widely disseminated, growing over the greater part of Southern Europe, in the Levant, and in Western Asia. The variety which produces the galls is usually a mere

Fig. 2682.—The Nutgall Oak, Showing Leaves, Acorns, and One Nutgall. (Baillon.)

shrub less than six feet high. The insect named is a small, wasp-like fly. The female punctures certain of the unexpanded buds, leaving a single egg in each, thus causing it to develop into a gall, instead of a leafy branch. A spherical cavity is formed by the growth of the gall, its lining being of a different structure from that of the remainder of the gall. The larva, when fully developed, gnaws its way out, leaving a pinhole perforation. After this occurrence the gall presents quite a different appearance, being larger, lighter in color and weight, and less rich in active constituents, such galls being distinguished in commerce as White galls, and less highly esteemed than those collected at an earlier period.

Description.—Nearly spherical, about 2.5 centimeters (1 in.) or less in diameter, with a short stipe, the surface smooth, except for a number of short, thick tubercles toward the summit; externally deep greenish- or bluish-gray or blackish; heavy and hard, but readily broken with a hammer, exhibiting a more or less dense granular fracture, sometimes with a waxy luster; internally, yellowish or pale brownish-gray, with a central nucleus or a cavity containing the more or less perfectly developed insect. The granular tissue of the nucleus is mostly filled with small starch granules and surrounded by a layer of thick-walled cells forming a shell, on the outside of which is the cellular tissue containing the tannin. This tissue has often a radiated appearance near the shell, and contains toward the surface small scattered bundles of vascular tissue. Nutgalls are nearly inodorous and have a very astringent taste. Light, spongy, and whitish-colored nutgalls should be rejected.

Nutgalls are distinguished in commerce according to their color, the *blue* or *black galls* of Syria (Aleppo) being preferred. *Smyrna galls* are usually of a grayish olive green, more spongy in texture and intermixed with *white galls.*

Many other varieties of galls, especially the Chinese variety, have a similar composition and uses, though substitution or adulteration of the medicinal article is hardly to be looked for. Chinese galls are large, occasionally three inches in length, oblong-ovoid and somewhat flattened, coarsely tuberculate, the tubercles very irregular in size and often prolonged into branches. This gall is of a yellowish-gray color, densely and softly tomentose or velvety, light in weight and hollow, the wall being thin and crustaceous.

Nutgalls contain upward of sixty per cent. ot gallotannic acid, two or three per cent. of gallic acid, occurring as a natural derivative of the former, and small amounts of resin, sugar, and starch.

Action and Uses.—The properties of nutgall are those of tannic and gallic acids, in a degree corresponding with their percentages as stated above, and the reader is referred to those drugs for an account of its action and uses.

The official preparations of nutgall are the tincture, containing twenty per cent. of nutgall with ten per cent. of glycerin, and the ointment, which consists of twenty per cent. of the drug rubbed up with eighty per cent. of benzoinated lard.

Henry H. Rusby.

Gallanol—gallic acid anilid, gallanilid [$C_6H_5.NH.CO.C_6H_2(OH)_3$]—is obtained by heating at 150° C. gallic acid and anilin. It occurs as colorless or grayish crystals, slightly soluble in cold water or readily soluble in boiling water, alcohol, chloroform, and ether. It has been used in cases of psoriasis, chronic eczema, and other skin diseases. It is used in the form of an ointment, or solution, or dusting powder, in strengths varying from five to twenty per cent. Before this remedy is applied, the skin should always be cleansed with an alkaline soap solution.

W. A. Bastedo.
R. J. E. Scott.

Gall-bladder and Gall-ducts, Diseases of.—Catarrhal Inflammation.—*Synonyms:* Catarrhal jaundice; Icterus simplex; Icterus catarrhalis; Icterus gastroduodenalis. Since the investigations of Wyss, Charcot, Legg, and others, a broader significance

has been given to catarrh of the bile ducts than formerly; and at the present time pathologists are wont to include in the term all forms of jaundice save that due to stenosis and non-inflammatory occlusion of the ducts (by foreign bodies, growths, external pressure, etc.), or to a narrowing occurring as a sequeenc of a previous inflammation—catarrhal, suppurative, or exudative (see the section on Stenosis, below). For a full discussion of these questions, see *Jaundice;* suffice it to say that to a catarrh of the finer bile ducts has been attributed the jaundice of acute yellow atrophy of the liver, of phosphorus and other forms of poisoning, and of the various fevers, thus narrowing the limits of the so-called hematogenous jaundice. This section will be devoted only to an account of catarrhal inflammation of the bile ducts in the common acceptation of the term.

Etiology.—A predisposition to catarrh of the bile ducts is said to exist in persons of a bilious temperament. Persons liable to catarrh of other mucous membranes are prone to this affection. It arises very frequently from an extension of catarrhal inflammation from the stomach and duodenum, and the causes which excite the latter condition are prominent in the etiology of the former. Hence an attack may occur as the result of exposure to cold and dampness, of checking of the perspiration, of errors in diet, of overeating, and of the ingestion of rich or fatty food and of acrid substances, as well as of certain drugs and stimulants. A debauch is often followed by an attack, and the inhalation of noxious vapors and foul gases has been known to excite the disease. The so-called "epidemic" jaundice is thought to be due to a poison introduced from without, through the food drink, or air. Lesage, Demelin, and Thompson[1] consider such cases as of purely intestinal origin. Some epidemics, however, have the characteristics of an acute infectious disease and are attended with considerable mortality. Mennert's report of the Saxony epidemic of 1889 includes 518 cases, of which seventy-three per cent. were in children. There were thirty deaths. Weil's disease (infective jaundice) has been considered by some to be a modified typhoid infection and Rolleston describes it as an infection due to the *Bacillus proteus.* The writer has seen a case clinically Weil's disease from which Friedländer's bacillus was cultivated. It is probably more correct to consider Weil's disease as a separate infective clinical condition. Several cases of typhoid fever with marked jaundice at the onset have been reported by Ogilvie,[2] and their resemblance to this disease noted. The Widal reaction should be of great value in this regard. Dalgleish[3] speaks of an extensive epidemic of catarrhal jaundice, at Bloomfontein, which bore a strange relation to the prevalent typhoid and dysentery. Whole families might be attacked, but more frequently it was seen that one or two of a household might have jaundice while the others would be affected with typhoid or dysentery. The disease in most instances ran an afebrile course, was atten ded with marked gastric symptoms, and was not of as long duration as simple catarrhal jaundice. The possibility of this epidemic being a modified typhoid infection has not escaped notice. It is to be remembered that jaundice is not a common condition in typhoid fever, and that cases of jaundice not infrequently give a Widal reaction with concentrated sera.

An extensive epidemic occurred in Michigan during the summer and fall of 1897. Six hundred and seventy-five cases were observed, mostly in children. The affection was commonly more severe in adults. Whole families were attacked. Usually after a few days of indisposition, light fever, gastrointestinal disturbances, and jaundice, more or less marked, would appear, the symptoms then abating. Jaundice in this epidemic was always of short duration. The liver was rarely enlarged.[4]

In addition to the causes which set up the catarrh of the bile ducts, either coincidently with, or secondarily to, the gastroduodenal catarrh, there are other local causal conditions existing in disturbances of the portal circulation. Obstructive cardiac disease and impeded pulmonary circulation from lung disease or feeble heart lead to hepatic congestion, venous stasis, and consequent catarrh of the mucous membranes. Tumors in the abdominal cavity, enlarged glands, or the enlargement of any of the organs, by interfering with the portal circulation, may set up a catarrh. Dutton Steele reported a case of jaundice apparently due to kinking and obstruction of the bile duct from extreme gastroptosis and enteroptosis.

Catarrhal inflammation of the bile ducts, with or without gastroduodenal catarrh, is caused by malaria, by syphilis (in the secondary stage), and by gout (Murchison). Acute phosphorus poisoning and lead poisoning are often attended with gastrohepatic catarrh. The jaundice that accompanies cholera, typhus, typhoid, pneumonia, pyemia, septicemia, and other fevers, may be due to a catarrh of the bile ducts, through an active hemolytic process with deposition of the blood pigment in the liver and tissues is considered now the more probable condition.

Direct irritation of the mucous membrane of the ducts by mechanical causes, as by the passage of gallstones or by the presence of parasites, frequently causes a catarrh which may be local or diffused. Finally, it is said that pathological states of the bile itself irritate and excite inflammation of the ducts. In persons who are starving, from choice or necessity, it is said that the bile, which is retained in the gall-bladder, becomes acrid and sets up an active inflammation. The jaundice that in rare cases accompanies cirrhosis, amyloid and fatty liver, is due to a catarrh of the ducts, brought about by the intrahepatic obstruction of the biliary canaliculi.

The season of the year is believed to have some influence on the production of biliary catarrh—spring and autumn being the favorable periods; hence the terms icterus vernalis, autumnalis, etc. Sex exercises no influence on the frequency (Ewald, von Schüppel); yet, in our cases, excluding "epidemic" jaundice, the males were largely in preponderance. The disease is most frequently seen in the early period of life, and after forty a jaundice is not likely to be due to primary catarrh, although in a case—under the care of Dr. Musser, the patient was seventy years of age. Firemen, puddlers, stokers, and laborers who are exposed to extremes of temperature are liable to the affection.

Morbid Anatomy.—In the milder forms post-mortem inspection reveals nothing, for, as we often find in a laryngitis so severe as to cause stenosis, the congestion and edema subside after death. In the more severe varieties, redness, swelling, and ecchymosis of the mucous membrane are observed. The lumen of the ducts, if not occluded by the flaccid lining membrane, is filled with proliferated epithelium and mucus. The latter may be bile-stained, especially at first, or may be clear and viscid. A plug of firm mucus often stops the orifice. The papilla stands out prominently on the duodenal mucous membrane and is red and softened, but a probe readily penetrates the duct, and bile may be forced out by pressure of the hand on the gall-bladder, although the feeble vis à tergo of the biliary secretion during life is not sufficient to overcome the obstruction. The duct, beyond the seat of the catarrh, is stained with bile. In the more advanced or prolonged cases the ducts are completely blocked by a somewhat firm, gray mucus, intermingled with proliferated epithelium and leucocytes, the congestion is more intense, ecchymoses are more common, and a more marked thickening of the mucous membrane is observed, due to cellular infiltration. Denudation of the epithelial surface may take place, ulcerations develop, and the terminal ducts undergo inflammation and dilatation from retention

of, and irritation caused by, the imprisoned bile. Anatomically, catarrhal inflammation of the ducts may be divided into an acute form of ten days' duration (no lesions after death, or only congestion and edema), a subacute form, lasting from two to six weeks (with the above lesions, cell proliferation and mucus formation in abundance), and a chronic form, continuing from two to six or eight months (excessive catarrh, abrasion, ulceration, dilatation, stricture, and retention abscesses or cysts). Catarrhal inflammation results either in the return of the parts to a normal condition, or in a stricture of the ducts (see the section on Stenosis of the Ducts, below) and its sequences, or in a "biliary" or "hypertrophic" cirrhosis of the liver.[5] Dropsy of the gall-bladder occurs also as a sequence of catarrh of the cystic or common duct, with occlusion.

The seat of the catarrhal inflammation may be limited to the finer ducts, to the common duct, or to the cystic duct and gall-bladder. Thudichum (1863), and in recent times Draper,[6] McArthur, Hawkes, Rolleston[7] describe a catarrhal inflammation of the finer ducts in which perfect biliary casts and stones are formed. Meckel regards such casts as frequently forming the nuclei of gallstones and has given the name of "lithiatic catarrh" to the condition. Robson suggests the term "desquamating angiocholitis." The *pars intestinalis* was formerly considered to be the only portion of the common duct involved in catarrhal icterus. If the finer ducts are the seat of catarrh, as in phosphorus-poisoning, the larger ducts are pale and covered with a film of mucus or a small amount of thin bile. If the gall-bladder is the exclusive seat, its mucous membrane undergoes changes similar to that of the duct; its contents are a dark-colored inspissated bile and mucus in abundance, or a thin, watery mucus or muco-pus fills the bladder. According to Mayo Robson, catarrhal cholecystitis, or chronic catarrh of the gall-bladder, without jaundice, forms a distinct and definite disease frequently mistaken for cholelithiasis and only recognizable at operation, when nothing but thick, ropy mucus is found in the bladder or ducts. This mucus, often in the form of sago-like plugs, gives rise, in its passage, to the gallstone-like attacks. In these, as a rule, medical treatment is sufficient, but in persistent attacks, in which no gallstones are passed in the feces, no jaundice develops and no tenderness is present in the gall-bladder region, the operation of opening and draining the gall-bladder is urged. Robson early reported the cure of several cases by this procedure and at present, drainage of the gall-bladder or even at times cholecystectomy is freely practised in chronic gall-bladder cases.

The histological changes in the parenchyma of the liver vary. Either the appearances of a liver long stained with bile are found, or the atrophic and degenerative alterations seen in stenosis of the ducts are observed, or a "biliary" cirrhosis develops.

Symptoms, Course, and Duration.—These depend upon the cause; if this be one that is readily removed or that passes off quickly, the symptoms are mild and the duration is brief, as in the catarrh that succeeds the passage of a gallstone. If the affection arise from obstructive heart or lung diseases, the symptoms are mild, but the duration is long. The catarrh that accompanies a gastroduodenitis is the most severe and protracted. The mode of onset also varies with the cause. The gastroduodenohepatic form is usually preceded by gastric symptoms for three or four days; while those due to other causes follow the usual manifestations of these causes.

The description which follows is that of a catarrhal inflammation of the ducts supervening upon duodenal catarrh, which may be regarded as a type of the disease under consideration. The affection may begin in any of several different ways:

The gastroduodenal symptoms may precede the hepatic by three or four days; or the first observed symptom may be jaundice; or the attack may be ushered in by a chill, followed by fever with gastric symptoms and, in a few days, by jaundice. Loss of appetite, a tongue covered with a heavy yellow fur, pasty and bitter buccal secretions, and an offensive breath, are prominent. Nausea in the mornings or at the sight of food, and vomiting of a glairy mucus or, early in the attack, of a bitter, bile-stained, acrid fluid may occur. At the same time there are epigastric distress, weight and fulness, some tenderness on pressure, soreness, or even marked pain. Later, there are pain and tenderness in the right hypochondrium and over the liver. It is denied by some authorities that the liver and gall-bladder are enlarged, but I have observed enlargement of the former constantly in chronic cases. The abdomen is usually distended with gas, and eructations of gas and acid gastric juice may occur. The bowels are constipated, or a diarrhea from indigestion may occur in the early stage. In a few days jaundice appears; first the conjunctiva, then the face, and in a short time the entire body is discolored. The icterus varies in extent and degree. The conjunctiva alone may be affected, and it may be merely of a faint yellow tinge or, in chronic cases, of a deep bronze. The fever, which is from 100° to 103° F., generally subsides with the advent of the jaundice, but it may continue for ten days or two weeks as a simple continued fever, the so-called "gastric" or catarrhal fever. The well-known symptoms and effects of obstructive jaundice are present (see article on *Jaundice*).

It is important, to remark the uniform persistence of the jaundice. Probably the most characteristic symptom is the slow pulse, which often distinguishes this form from other varieties of jaundice. Fagge calls particular attention to this symptom. Headache is present often in the beginning, with or without vertigo. After the jaundice becomes developed, the usual nervous symptoms of the disease are manifested.

If the case be a mild one, the gastric symptoms first subside, and the jaundice gradually disappears, without any serious disturbances of nutrition. In the more protracted cases, however, anemia, emaciation, and prostation are marked, the degree depending on the duration of the disease.

The mild idiopathic cases continue for from ten days to three weeks, the more severe ones for from six to ten weeks, and the more obstinate cases as long as five or six months.

Should stricture of the duct take place as a sequence of the catarrh, and should suppuration of the ducts occur, and abscesses form, fever of an irregular type, often with chills, and with exhaustive sweats, will usually be present. In these instances the liver and gall-bladder are enlarged, and inflammation of the latter organ may take place.

Catarrhal inflammation of the gall-bladder alone is characterized by pain and tenderness in the right hypochondrium, by enlargement of the gall-bladder, and by slight fever, with, at times, nausea. Jaundice may not be present, but in many cases an accompanying gallstone in the gall-bladder or cystic duct may give rise to jaundice from an inflammatory occlusion of the common bile ducts by extension. Riedel is quoted by Gumprecht[8] as stating that two-fifths of the cases of jaundice in cholelithiasis arise in this way (Mayo Robson).

Diagnosis.—The presence of one of the causes or antecedent pathological conditions just noted, the early age and previous good health of the patient, the sudden and uniform development and persistence of the jaundice, and the absence of the physical signs of organic disease of the liver, clearly indicate simple catarrhal icterus. Care must be taken not to confound it with the jaundice of acute yellow atrophy, and it must not be forgotten that, in apparently the most

simple jaundice, grave cerebral and other symptoms due to acute atrophy may arise. Acute yellow atrophy may occur at an early age in the pregnant female; the more marked epigastric pain, the jaundice of the upper portion of the body, the vomiting of blood, the cerebral symptoms, and the alterations in the size of the liver and spleen serve to distinguish it.

The jaundice due to obstruction by gallstones develops quickly, is quite marked, and varies in its intensity from time to time; paroxysmal and persistent pain is more pronounced than in the simple form; the patient is usually a woman, and the attacks occur late in life. The diagnosis must be made between jaundice from simple obstruction and that caused by pressure on the ducts. The physical signs and clinical history of the many forms of external pressure must be considered (see section on Stenosis). Pain, fever, sweats, increase in size and tenderness of the liver and gall-bladder, with prostration and emaciation, occurring late in the disease, indicate stricture and the formation of abscesses, or purulent inflammation of the ducts. If the jaundice continues longer than two months, if the pulse is frequent from the first, if sweats are marked, if emaciation rapidly ensues, and if the patient is over thirty years of age, it is more than possible that some affection other than simple catarrh, and not revealed by physical signs, is present. An important observation in this connection is that frequently, in malignant disease of the liver or bile ducts, jaundice due merely to an associated catarrh may disappear under treatment, the disease meanwhile persisting and progressing. The jaundice due to pressure or obstruction will be little, if at all, influenced by any means (Mayo Robson). It has been suggested that the existence of a diarrhea in the course of catarrh of the bile ducts would indicate closure at the orifice; for then the pancreatic duct would likewise be occluded, and diarrhea, a well-known symptom of pancreatic disease, would ensue. The presence of fat in the stools would also point to this conclusion.

Prognosis.—This is usually favorable, but depends more or less on the cause. Gastrohepatic catarrh terminates favorably. The presence of symptoms indicating purulent inflammation of the duct renders the prognosis grave. Prolonged jaundice, with the advent of marked cerebral symptoms, is very serious. The possibility of the development of icterus gravis should not be forgotten. The prognosis is seriously modified by inactivity of the kidneys; cerebral symptoms are not so liable to occur if the renal secretion is abundant. Hemorrhage, in any of its forms, is a bad omen.

Treatment.—The line of treatment to be adopted depends entirely on the cause of the catarrhal inflammation. If it arise from cold and exposure and is seen early, a warm bath or a vapor bath, saline cathartics or of small doses of tartar emetic, are of service. Full doses of quinine and Dover's powder at bed-time, with a light purge in the morning, will often relieve the general symptoms of "cold," and exert a favorable influence upon the local catarrh. If the cause of the disease is a coexisting gastroduodenal catarrh, a thorough lavage is often followed by good results. Large draughts of hot water, either at bed-time or repeated throughout the day, are grateful and beneficial. They are made more palatable by the addition of some one of the alkaline citrates. At the same time an alkaline purgative, largely diluted, should be employed, and later gastric sedatives or the mineral acids. Patients with catarrhal jaundice rarely apply for treatment until some time after the jaundice has appeared, and as this is generally due to a gastro-intestinal catarrh, a system of treatment that has usually been successful in these cases may here be presented. First, in the acute form: a mercurial purgative is administered. I usually prescribe from one-twelfth to one-third of a grain of calomel, in combination with from three to ten grains of bicarbonate of sodium every two hours, until eight or twelve powders are taken. If the bowels are not acted on freely by this combination, it should be followed by a saline laxative. At the same time light sinapisms are applied to the epigastrium. After the bowels are freely opened, it will often be found that the tongue has already become somewhat cleaner, and the bad taste, the nausea, and the vomiting have been relieved. In the more chronic cases in which the gastroduodenal catarrh has subsided, we have other conditions to deal with, and the indications are to remove the obstructing mucus and reduce the inflammation and thickening of the ducts. These indications may be met by remedies that in a measure increase the secretion of bile and thereby drive away the obstruction, or by drugs that render the mucus less viscid and that relieve the congestion. Among the remedies of this latter class the alkalies are of great service, and may be given in the form of the alkaline effervescing waters, as the Carlsbad, Vichy, or Hathorn waters, or the salts of ammonium, sodium, or potassium may be used. Bartholow advocates the phosphate of sodium in dram doses; Guiteras, iodide of potassium in small doses freely diluted, and taken fasting. The muriate of ammonium is one of the most reliable alkalies; it may be given in ten- or twenty-grain doses, three or four times daily, combined with an equal quantity of powdered licorice, and dissolved in water. Ipecacuanha has been advocated in small doses, as one-half grain or one grain, frequently repeated, for the same purpose.

To increase the secretion, nitrohydrochloric acid, the vegetable hepatic stimulants, benzoate and salicylate of sodium, and alkaline waters are of service. The alkalies should be taken in a large amount of water, preferably hot, on an empty stomach, and by slowly sipping the fluid. Emetics have been used for their mechanical effect, but care must be observed lest their too free use incite a fresh catarrh or aggravate the one already existing; thorough lavage is preferable.

Mosler and Krull have successfully treated catarrhal jaundice with enemata of cold water. Once in twenty-four hours, they inject, slowly from one to four pints of cold water (59° F.) into the rectum, and require the patient to retain it as long as possible. With each injection the temperature of the water is gradually raised.

By pressure on the fundus of the gall-bladder, if it can be readily grasped, directing the force toward the vertebral column, Gerhardt has succeeded in overcoming the obstruction and relieving the jaundice. Such a procedure must undoubtedly be a dangerous one as the gall-bladder wall is thinned and weakened. No doubt Kussmaul's treatment of intestinal obstruction by washing out the stomach, would be of service in this affection.

The diet should be bland and non-irritating. Fats, sugars, and, as a rule, starches, should be excluded, as well as spirituous or malt liquors. Light broths, beef-tea, milk, and later, meats, fish, eggs, and oysters should be the chief articles of diet. Afterward tomatoes, lettuce, spinach, celery, and the like may be used.

The troublesome, and at times serious, effects of the jaundice will be treated of under that heading. (See *Jaundice.*)

Purulent, Ulcerative, and Croupous Inflammation.—*Synonyms:* Cholecystitis et cholangitis suppurativa, diphtherica, exulcerans, or crouposa (Schüppel); Exsudative Entzündung der Gallenwege (Frerichs).

Etiology.—According to Bloch, in disease of the gall-bladder and bile ducts the bile soon becomes infected with various microorganisms, principally *B. typhosus, B. coli communis,* staphyloccoci, streptococci, and pneumococci. Any condition obstructing

the flow of bile invites bacterial infection (Charcot and Gombault,[9] Netter,[10] Terrier[11]). Hence foreign bodies, such as gallstones or parasites, in the biliary passages, stenosis and occlusion of the ducts in any part of their course, readily pave the way for any infecting agent.

Fütterer has shown that in a very few minutes after the injection of organisms into the circulation they appear in the bile. Flexner and Chiari have demonstrated the constant presence of typhoid bacilli in the bile in patients dying of typhoid fever, the latter observer describing acute inflammatory lesions in thirteen of nineteen such cases without any gross obstruction in the biliary passages Camac records an instance of acute cholecystitis with operation in the first few days of an attack of typhoid fever. Cases of acute cholecystitis due to the *Bacillus typhosus* without previous history of typhoid fever are reported by Cushing and Mitchell. Hunner describes another occurring eighteen years after an attack of typhoid, with operation, and isolation of the typhoid bacillus. It can safely be assumed that bacterial infection exists in all cases, and that acute inflammatory infection of the biliary passages may occur without obstruction in many of the acute infectious diseases. Cases of acute phlegmonous cholecystitis and gangrenous cholecystitis are probably only instances of very severe infection, which may spread so rapidly that general peritonitis may occur in a few days. Pratt,[12] shows the frequency of cholecystitis due to the *Bacillus typhosus*. It therefore seems probable that cholecystitis may begin as a primary local typhoid infection. Pearce[13] has described an instance of the presence of a leptothrix in an acute cholecystitis, the organism being also found in gallstones present in the gall-bladder.

Ulcerations of the biliary passage are most frequently due to gallstones. Carcinoma is a common cause, and ulcerations have been met with in typhoid fever and in cholera. The sequelæ of ulcerations, stricture, perforation, fistula, etc., make the condition more serious than it might otherwise be.

Croupous or membranous inflammation of the gall-bladder and ducts may occur as the result of irritation from the passage of a gallstone, or it may be a further stage of catarrhal inflammation. Powell[14] noted that membranous enteritis was frequently accompanied by gallstone-like attacks, and it has been suggested that gallstone colic may be the exciting cause of membranous enteritis. Robson thinks a membranous or croupous formation in the gall-bladder or ducts, with passing of the membrane or pieces thereof, accounts for the painful, gallstone-like attacks. Fenwick[15] discovered a true cast of the gall-bladder in the feces twenty-four hours after a very severe attack of hepatic colic. A similar cast had been found two weeks previously under similar conditions. In all suspected gallstone attacks, in which no stones are found in the feces, search should also be made for fleshy, tube-like structures or fragments thereof, as they alone may be responsible. Robson is of the opinion that the gallstone-like attacks seem not infrequently, in subjects of membranous enteritis, to indicate involvement of the biliary passages in a similar condition. Extension of purulent inflammation from adjoining veins or from hepatic abscesses appears to have been the cause in some instances. It is certainly true that a multiform inflammation of the ducts may occur by extension of inflammation from some one localized focus, as an ulceration due to gallstone. This form of biliary inflammation is usually met with in advanced life. Croupous inflammation of the biliary passages is also caused by gallstones.

Morbid Anatomy.—The cases that have been observed by the writer presented nearly all the anatomical appearances that occur in cholangitis and cholecystitis.

There are observed a swollen, thickened mucous membrane, of a pale ashen or slate-gray color; uniform or saccular dilatation of the ducts; and abscesses in the periphery of the duct or along its course. Often a gangrenous appearance of the duct wall is seen. The dilated canals and the abscesses contain yellowish-green bile and pus, sometimes thick and ropy, and often ichorous. Ulcers are often found, superficial in character, large and irregular, or quite deep and small. From the healing of the ulcers and the contraction of the cicatrix, the ducts beyond the obstruction are obliterated. This may also occur after exudative inflammation; and in the liver fibrous bands, the remains of the biliary channels, are often seen. The tissue of the liver beyond becomes sclerosed, and the cells proper undergo atrophy and degeneration. The abscesses of the liver may extend into a contiguous vein, or may ulcerate toward the surface; hence a perihepatitis is often seen. Sometimes one large abscess alone is found; rarely do abscesses become encapsulated. The ulcers that have formed are often covered with a gray, gangrenous detritus, which is removed with difficulty. In these inflammations of the ducts, fibrin cylinders, well moulded and easily removed, are found. The hepatic structure undergoes some changes: in the mild forms either a connective-tissue overgrowth lights up, or a diffuse hepatitis arises; in the chronic forms with jaundice the liver cells are icteric, compressed into various shapes, and present the appearances of having undergone fatty or granular degeneration.

As a sequence of purulent or exudative inflammation of the gall-bladder, marked phenomena are observed. The mucous membrane undergoes the usual changes, the walls become thickened, and the cavity is filled with pus, muco-pus, or pus and bile. Ulcerations are formed, and may penetrate to the peritoneal cavity.

Adhesions take place between the gall-bladder and neighboring structures, fistulæ develop, and often the adjacent tissues are filled with pus. The ulcers are single or multiform. In mild cases a fibrous thickening of the walls of the gall-bladder and its surroundings takes place, followed by contraction and obliteration of the organ. Frequently the gall-bladder is found firmly contracted around imprisoned gallstones. On the other hand, the gall-bladder may undergo extreme dilatation and enlargement, producing an empyema. If the phlegmonous inflammation be confined to the walls, this structure may undergo calcareous degeneration (so-called "ossification").

Symptoms, Course, Duration.—The symptoms are those of the causal condition—as one of the infective fevers, gallstones, etc.—combined with the local inflammatory manifestations. Often the condition is not recognized during life, or there may be present only an irregular fever with rigors. If, after an attack of hepatic colic, fever of an irregular type, chilly sensations, or sharp rigors occur, and prostration ensues, independently of any paludal affection, we may suspect an infective inflammation of the bile ducts. In these cases, the jaundice, which is usually present, deepens, pains in the hepatic region are marked, and a fixed local pain in the right hypochondrium is complained of. If the gall-bladder is involved, the physical signs of enlargement of that organ are observed (see the section on Enlargement of the Gall-bladder). As the inflammation and infection progress the symptoms of perihepatitis, intrahepatic suppuration, local or general peritonitis, occur. In addition to pain in the region of the gall-bladder, we have pain and tenderness frequently in the epigastrium. With or without this local inflammation, vomiting is frequent, hemorrhages occur from the stomach and bowel, and often a diarrhea is started. Budd believed that many cases recovered. If so, there must have been spontaneous emptying of the ducts into the intestine, or an ulceration and

perforation into the intestinal tract somewhere in its course. An increase of local tenderness and the presence of tumefaction and redness show that the direction which the pus is taking is toward the surface. Discharge of the abscess in this position leads to the formation of a cutaneous biliary fistula. Broncho-biliary fistulæ are recorded, with prolonging of life from the discharge of pus in this ununsual manner. If these fortunate terminations do not occur, and in cholangitis they are not to be expected, the fever continues, the gastrointestinal system gives way completely, septicemia and cholemia frequently occur, and finally death. A fatal result may occur from exhaustion, due to the combined influences of the fever, the suppuration, the gastrointestinal disturbances, and the jaundice; or a peritonitis from perforation or rupture of the gall ducts or a pylephlebitis may hasten the fatal termination. Hemorrhages are also liable to occur if the jaundice is of long duration, and they will add to the extreme debility. Cholecystitis, due to foreign bodies or to obstruction of the cystic duct, may run its course, and the contents of the bladder be discharged into the neighboring hollow viscera or externally, without the supervention of grave general symptoms local phenomena and physical signs alone indicating its presence. The lodging of a gallstone in the common duct is often and usually associated with a peculiar fever and train of symptoms, the so-called hepatic intermittent fever of Charcot. Osler, Fenger, and Courvoisier describe a ball-valve action of gallstones lodged in the diverticulum of Vater, the bile readily flowing by the stone but becoming easily obstructed and infected under certain circumstances, producing the characteristic ague-like paroxysms which may be frequently repeated (the recurring jaundice deepening with each attack), or may occur at intervals of months or years. Each attack probably represents a mild infective cholangitis which may quickly subside or may run into the more serious conditions already mentioned as occurring in infection of the biliary passages. Leucocytosis, more or less marked, absence of the malarial parasite in the blood, resistance to quinine, the irregularity of the paroxysms, and the deepening jaundice should distinguish the conditions from malaria. Moynihan[16] states, however, that in twenty-five per cent. of his cases jaundice was completely absent. There is usually a history of previous gallstone colic. Robson states that in his experience several impacted stones were as frequently found as a single stone, freely movable and acting like a ball-valve.

Diagnosis and Prognosis.—The diagnosis is uncertain, and when the symptoms are latent it is manifestly impossible to make a diagnosis. Pain and swelling of the liver, with tenderness on pressure, irregular chills and fever in a person who is jaundiced or who has had an attack of gallstones, are strong evidences of exudative inflammation. Cholecystitis may be recognized by local symptoms (see section on Enlargement of the Gall-bladder). The prognosis is very unfavorable on account of the many accidents that may arise. Intrahepatic suppuration is almost invariably fatal. A single accessible area of suppuration offers a chance for surgical relief, external biliary fistulæ are occasional examples of natural cure.

Treatment.—Medical treatment is powerless to aid. Unless the disease shows signs of resolution it is now generally advised to open and drain the gall-bladder in all cases of cholecystitis. In infective and suppurative cholangitis, opening of the gall-bladder offers the only chance and is followed in many cases by cure. Terrier[11] and Robson insisted upon the value of this proceeding, and it is now recognized as the only rational procedure; areas of suppuration on the liver surface are opened and drained. Removal of stones from the common duct is performed and is indicated in persisting evidence of obstruction and infection (Halsted).

Stenosis and Occlusion of the Gall-ducts.—The canal is occluded when it is completely closed; partial closure, sufficient to cause obstruction, is denominated stenosis. These conditions may be congenital or acquired; the acquired forms alone are treated of in this connection. The causes are the same in both cases, and the results are similar.

The obstruction may be due to foreign bodies within the duct, to diseases of the duct walls, or to external pressure.

1. The foreign bodies which may find lodgment within the ducts are gallstones, parasites, or, in rare cases—if the orifice of the duct is very patulous, as occurs after the passage of a gallstone—cherry pits, plum stones, or raisin seeds. The gallstones are generally impacted in the cystic duct, or at the mouth of the common duct. The common round worm has been found in the lumen of the duct. The liver fluke also causes stenosis, but complete obstruction is not effected without the intervention of local inflammatory symptoms. The rupture of an echinococcus sac into the ducts and the discharge of the vesicles cause temporary obstruction. Complete closure may be caused by multilocular echinococcus tumors, which cause infiltration, thickening, and ulceration of the wall of the duct. The hepatic and cystic ducts are chiefly involved.

2. The obstruction may be due to chronic catarrhal inflammation, to purulent and ulcerative inflammation, to carcinoma or other morbid growths of the ducts, or to a perihepatitis with thickening of the investing membrane, leading to hypertrophy of the subserous connective tissue, and occlusion of the duct. In the inflammatory forms, granulations in apposition coalesce, and the formation of a stricture ensues. When ulceration has previously occurred, the stenosis is due to the contraction of the cicatrix. The causes mentioned in the sections treating of those affections are the primary causes, therefore, of the stenosis. The lumen of the duct becomes absolutely imperforate in the inflammatory varieties, and the occlusion may extend over a variable length, though it most frequently exists in the common duct. The lumen is not completely occluded in cicatricial stricture, but is impermeable, and is not unlike a urethral stricture. Local or extended thickenings of the duct causing stenosis are due to a connective-tissue hyperplasia, which originates in a previous catarrhal inflammation. The cicatrix of a duodenal ulcer sometimes includes in its grasp the duodenal opening of the common bile duct.

Carcinoma of the biliary passages will be treated of in a separate section. The perihepatitis, which includes in its course the investment membrane of the ducts, is caused by general peritonitis, by right-sided purulent pleurisy, by affections of the liver and adjacent organs, which set up irritation (as, for example, cancer, cirrhosis, ulceration, etc.). As the peritoneal thickening and the new inflammatory tissues grow in age, they contract and thus encroach on the lumen of the ducts. Syphilis is said to be a cause of this local inflammation.

3. External pressure is caused by disease or displacement of contiguous organs. Named in their order of frequency, it is often found that affections of the pancreas or of the lymphatic glands in the hepatic fissure, the duodenum, the stomach, the omentum, and the kidney are the sources of pressure. Carcinoma or hypertrophy of the pancreas; carcinoma, tuberculosis, or lymphosarcoma of the lymphatic glands; carcinoma of the stomach, duodenum, or omentum, and tumors of the kidney (hydronephrosis, sarcoma, or carcinoma) are the essential pathological conditions which lead to the occlusion. Aneurysms of the aorta (Hatton) and of the hepatic artery (Gairdner) cause obstruction. Very rarely tumors of the ovary and uterus, and fecal tumors, are the cause of occlusion.

The anatomical sequences of occlusion and stenosis of the biliary passages are dilatation of the ducts or gall-bladder behind the obstruction, catarrhal or suppurative inflammation of the ducts, enlargement of the liver, at first from the excessive dilatation of the canals and then from a hypertrophic or biliary cirrhosis, and subsequent atrophy of the liver from pressure of the ducts on the secreting tissue or destruction of the cells by the connective-tissue overgrowth.

The dilatation of the duct is often extreme, particularly in cases not associated with gallstones. (See, however, Robson[17] and Swain.[18]) The common and hepatic ducts may be as large as the intestine, and their walls thin, although rupture rarely takes place. The ducts in the liver are also dilated to the size of the finger throughout their extent, even to the surface, causing it to have a vesicular appearance. The walls are not greatly thickened, and are lined with columnar epithelium. The mucous membrane is pale and smooth. The ducts terminate in large pouches, and numerous recesses are seen in the course of the cylindrical canal. Retention cysts are often found. At first the biliary channels are filled with bile only, but after a time this fluid is replaced by a secretion from the glands of the mucous membrane, which is limpid, viscid, and serous in character. The chemical and microscopical examination of the fluid gives no indication of bile constituents. The reaction of the fluid is neutral; it contains albumin. When this fluid is found in the bile ducts, bile is not secreted in them, and the mucous membrane of the ducts is in truth a cyst wall. Whatever bile is secreted is at once absorbed.

The liver is icteric and anemic; flaccid at first, cirrhotic afterward. The cells undergo atrophy and contain bile pigment and minute oil globules, and cloudy swelling of the protoplasm is observed. The changes peculiar to biliary cirrhosis are observed later.

A description of the changes in the gall-bladder is reserved for the section on Enlargement of the Gall-bladder.

The *Symptoms* are complex, and include the symptoms of the primary cause and those of biliary obstruction. Aside from the physical signs and symptoms of the causal disease, jaundice is the first symptom. As a rule, the yellowish tinge gradually changes to a deep olive-green color, and with it the changes in the urine take place; gastrointestinal dyspepsia is developed, and finally a veritable catarrh supervenes, with its full train of symptoms. Early in the disease weight and tension in the epigastrium and hypochondriac region are complained of, and enlargement of the liver and gall-bladder is observed. After a time pruritus comes on, and in from two to four months hemorrhages ensue. Loss of flesh and strength rapidly takes place. Soon, if death has not in the mean time resulted from the original cause or from some intercurrent disease, the symptoms of cholemic intoxication are likely to arise, and death results from this condition.

One cannot, within the limits of this article, discuss in detail all the forms of biliary stenosis and occlusion, and their differential diagnosis; persistent jaundice, the absence of bile in the stools and its presence in the urine clearly indicate an obstructive condition of the bile duct. There are some organic diseases of the liver, however, which give rise to jaundice in some other way than by means of occlusion. They should be distinguished from common forms of obstructive jaundice, on account of the opposite methods adopted for their treatment. Reference is made to atrophic and hypertrophic cirrhosis, to carcinoma, to syphilis, to tuberculosis, to simple and multiple abscesses, to simple and multiform hydatid disease, and to amyloid disease. The recognition of any of these is not difficult. The atrophic variety of cirrhosis is easily recognized by its well-known symptoms, but not so the so-called hypertrophic cirrhosis. The jaundice is intense, the liver enlarged and smooth, ascites is absent, paroxysmal pains occur, and irregular fever is present (Musser[5]). In the jaundice due to obstruction the liver is not so large, the gall-bladder is enlarged, while a distinct cause for the jaundice—as, for example, a tumor—may be discovered.

Having discussed the question of occlusion due to any one of the etiological factors previously noted, we may now be permitted to refer briefly, for diagnostic purposes, to these causal conditions.

1. *Foreign Bodies.*—If the obstruction be due to worms, the latter may be suspected if parasites or ova are seen in stools or vomit. In the case of hydatid cysts, which at times may burst into the bile ducts, with symptoms of hepatic colic, the diagnosis may be more readily made: first, by the previous history and physical signs of an hydatid tumor; second, by the disappearance of the tumor after the colic; third, by the subsequent occurrence of fever and local inflammation; and lastly, by the appearance of sacs or hooklets in the feces or aspirated matter.

Gallstones.—It is of the utmost importance to determine the presence of biliary calculi. To accomplish this is sometimes a very difficult matter; in fact, it is often a task impossible of accomplishment. The varying symptoms of cholelithiasis are so many that it is not possible to name one of them, or to present a group of them, for the purpose of making a diagnosis, without being able to give an exception to each and every one. The only absolutely definite sign is to see or feel the calculus, or to have it well demonstrated by an *x*-ray picture. If one has been passed by the rectum, it probably was the cause of the obstruction; if it have facets, a fellow-calculus may be the cause.[9] If it is not detected in the stools and the obstruction is persistent, exploration of the gall-bladder and bile ducts may be resorted to by opening the abdominal cavity. A history of the so-called "Hepatic intermittent fever" having preceded a persistent jaundice would suggest occlusion by impaction of a stone in the diverticulum of Vater.

Aside from these positive methods, a correct conclusion cannot be arrived at without a study of the case in its entirety; the age and sex of the patient, the habits, the family history, the temperament, all are important elements to be considered. If these circumstances are favorable, and if, in addition, the patient has had previous attacks of hepatic colic, *followed* by jaundice and the symptoms of duodenal catarrh; if constipation and putty-colored stools accompany the jaundice, the diagnosis is very probable. Then if, after impaction of a stone has taken place, the nutrition of the patient remains good for some time and the liver enlarges only slightly, while the gall-bladder does not increase appreciably in size, it is scarcely possible to name any other affection as the probable cause of the symptoms.

Campbell suggests that if, after aspiration of the gall-bladder, bilious stools are present, calculi may be assumed to be the cause of the obstruction. The relief of the tension allows the stone to recede and the bile to escape.

2. *Diseases of the Ducts.*—(*a*) Congenital closure. In an infant, a jaundice that continues for over four weeks, with supervening cholemia, is due most frequently to this condition. (*b*) Closure of the ducts by chronic catarrh of the duodenum, by adhesive inflammation of the ducts, by the cicatrization of an ulcer in the duct or at the duodenal orifice, and by fibrous bands. The first may be recognized partly by the history of the case and partly by the exclusion of attacks of catarrhal jaundice. Adhesive inflammation of the ducts is due either to the passage of biliary calculi or to a previous catarrh; cicatricial stenosis of the ducts as a result of gallstone laceration is surprisingly rare (Rolleston[7]). The respective symptoms of the two must be considered in each case.

Ulcers in the bile ducts are due to gallstones or are secondary to cancer or an infectious fever, as typhoid or cholera. Robson[17] says it has yet to be proved that typhoid ulceration causes obliteration and stricture of the ducts. In the former case, in addition to the symptoms of gallstones, we have, accompanying the ulceration, irregular chills and fever and extreme exhaustion, conditions not likely to be present in the early stages, at least, of simple impaction. If the symptoms of occlusion become developed after such phenomena or after an infectious fever, the exciting cause is probably the cicatrization of an ulcer in the duct. The well-known symptoms of duodenal ulceration precede for a long time the symptoms of obstruction of the biliary passages from this cause, and while it may be said that the gall-bladder is enlarged under such circumstances, it is not necessarily so when the seat of ulceration is in the duct. Closure of the ducts by fibrous bands may be inferred, if the cause (as syphilis) and the symptoms indicate a perihepatitis, and if other evidence of previous inflammatory trouble be present, as atrophy of the liver or ascites, due to pressure on the portal veins.

3. *Diseases External to the Ducts.*—(*a*) Carcinoma and other neoplasms of the liver and surrounding organs. A recognition of these affections can be obtained by the exclusion of other causes of obstruction, by the presence of tumors or nodules, and by the physical signs discoverable on palpation, etc.; also, when these are present, by the alterations of the functions of adjacent organs, and by the presence of the symptoms of malignant disease of these organs; and finally by the duration of the disease, the stenosis from carcinomata being of shorter course than that due to other causes. (*b*) Enlarged lymphatic glands. Obstruction from this cause is probable, if there be elsewhere present any of the well-known causes of hypertrophy of these glands, as carcinoma, tuberculosis, amyloid disease, etc. Amyloid disease but rarely causes jaundice, except in this way; its symptoms are too well known to be detailed in this article. (*c*) Aneurysm. This rare form of occlusion may be recognized by the pressure symptoms of a tumor located in the region of the duodenum, and by the physical signs of aneurysm.

The *course* of the disease, in occlusion of the biliary duct, is a chronic and most frequently a progressive one. It is a gradual march to death, except in cases in which foreign bodies cause the occlusion. Under these circumstances their removal by ulceration or the escape of bile around them may be followed by recovery. Death is the result of the original cause of the disease in many cases. Exhaustion or cholemia often brings about a fatal termination. The duration varies with the cause, and is modified by the onset of accidental complications. Complete occlusion may terminate in recovery even after a lapse of six years, probably by some accident such as the ulcerating through the intestinal and duct walls by an impacted stone. Treves operated successfully upon a jaundice of sixteen years standing and found obliteration and absence of the lower end of the bile duct. The prognosis is unfavorable, depending on the nature of the causal lesion. Hemorrhages render the prognosis very grave. The supervention of symptoms of cholemia is serious. The return of color to the stools is of more favorable import than is a change in the skin discoloration.

The *treatment* is mainly directed to the relief of symptoms. Medicinal remedies are of but little avail, and resort must be had to surgical measures. The regulation of the diet is of the utmost importance to the conservation of life (see section on Catarrhal Inflammation). Means must be taken to overcome the gastrointestinal symptoms that result from the absence of bile in the intestines. The bowels must be regulated, the secretion of the kidneys kept active, and the activity of the cutaneous glands promoted. Cholecystotomy, with the establishment of a permanent fistula, may be resorted to, and it may, by relieving pressure in some cases of gallstone or parasitic obstruction, promote a cure. Cholecystoduodenostomy has resulted in success in some instances and the advisability of resorting to it should be considered in a case of complete occlusion.

IV. Enlargement of the Gall-bladder.—Under this caption all forms of enlargement of the gall-bladder will be described, as it is by the clinical study of this manifestation of the disease that we, to a large extent, determine the nature of the ailment and the indications for treatment.

The gall-bladder is enlarged from the accumulation within it of bile, of pus, of mucus, and of gallstones, and from disease of its walls—carcinoma. Increase in size from bile, pus, or serum is usually styled simple dilatation. Carcinoma of the biliary passages will be treated of in a separate section. Accumulation of the fluids just indicated is due either to obstruction of the duct, or, in rare cases, to a paralysis of the muscular coat of the gall-bladder from overdistention. The dilatation from bile or pus may be temporary, and in such a case is caused by an obstruction, catarrhal in nature, or by the presence of a gallstone, which acts as a ball-valve in the lumen of the ducts. Enlargement from accumulation of bile is not common, but may occur with a concretion in the common duct. In this case it is usually of short duration, the bile being absorbed and replaced by mucus and the gall-bladder quickly shrinks.

The walls of the gall-bladder are uniformly distended and thinner than normal, the mucous membrane is smooth, and there are no adhesions to the surrounding parts. Sometimes the dilatation is extreme. From a patient of Babington's, three wash-basinfuls of fluid were withdrawn, and in another case the gall-bladder was so distended as to give the patient the appearance of having an ascites (Coupland). Lawson Tait and Kocher report cases in which distended gall-bladders were mistaken for ovarian cysts. Waring mentions a specimen in which the lower end of a distended gall-bladder formed the contents of a sac of a femoral hernia. The contents may consist at first of bile, but as the obstruction continues, this becomes more and more intermingled with mucus.

If serum accumulates, causing enlargement (hydrops cystidis felleæ), the obstruction is usually one that has existed for a long time. The inner surface of the mucous membrane is like a serous membrane in appearance, and the accumulated fluid is the result of secretion from this membrane. Adhesions are usually absent in dropsy of the gall-bladder, and the walls of the organ are much attenuated. It is usually found that in cases of obstruction by gallstone in the common duct the gall-bladder is small and contracted, due probably to repeated irritations from stones, the subsequent fibroid changes successfully resisting distention. Distention of the gall-bladder associated with marked jaundice is more frequently met with in new growths of the bile ducts or of the head of the pancreas. The chemical character of the fluid has already been described in the section on Stenosis.

Empyema or abscess of the gall-bladder results from an infection by microorganisms, either following upon some obstruction or irritation, or developing spontaneously. The condition is most frequently associated with gallstone, but tumors of the bile duct, typhoid and other fevers may be predisposing factors. Robson considers that "infection by pyogenic organisms is probably in every case the true exciting cause." The same anatomical changes are presented as have been described in the section on Purulent, Ulcerative, and Croupous Inflammation of the Gall-bladder. The walls of the organ are friable and easily ruptured. Adhesions to the surrounding parts are usualy formed, and a fistula is established. Pus, or pus and bile, and

almost always gallstones, make up the contents. The accumulation of gallstones in the gall-bladder, causing enlargement, is not uncommon.

Symptoms.—The presence of a tumor in the region of the gall-bladder is common to all forms of enlargement. The nature of a tumor observed in this region is determined by its position, size, and shape, by the characters revealed by palpation, and by the nature of its contents. The gall-bladder may be known to be enlarged when it is situated under the free border of the ribs, at a point where it is crossed by a line drawn from the tip of the right shoulder to the symphysis pubis (Janeway). As enlargement progresses, the direction which it takes is usually toward the umbilicus, or into the iliac fossa, the intestines are never in front of it. The tumor may be pyriform, oval, semiglobular, reniform, or heart-shaped. The size of the tumor varies from that of a walnut to that of a child's head; it may even distend the ribs on both sides (Coupland). On palpation, the tumor may be found to be fixed or movable, tender on pressure, firm, elastic, and fluctuating. If enlarged by gallstones, a grating sensation may be experienced on palpation, and the mass will be hard and firm.

The general condition of the patient and the symptoms presented depend on the cause of the obstruction (see the section on Purulent Inflammation).

Diagnosis.—A differential diagnosis must be made between enlargement of the gall-bladder and many forms of abdominal tumors—hepatic, gastric, duodenal, renal, pancreatic, and lymphatic tumors (see section on Occlusion, etc.). Abscess of the liver and hydatid disease must be excluded. In the former, the cause, the general and local symptoms, the position the induration, and then the softening and fluctuation of the swelling, should be noted. The painless, slow course of hydatid disease, the broad base of the cyst, the fremitus, and the result of tapping will serve, if taken with the negative symptoms of enlargement of the gall-bladder, to render the recognition of this disease possible. In multilocular hydatid disease the tumor resembles an enlarged gall-bladder containing calculi; like the latter, it is nodulated, hard, and tender, but it is associated with early jaundice, ascites, an enlarged spleen, edema of the lower eyelids, great emaciation and prostration, with rapid decline of the patient's general health—conditions which, excepting jaundice, are not likely to be present in gallstones. Floating kidney and renal and ovarian tumors have been mistaken for enlargement of the gall-bladder. Such an error will not often be made if it be remembered that the enlarged gall-bladder is more movable at the lower than at the upper portion; that one end is larger and more rounded than the other; that fluctuation may be present, and that biliary symptoms generally exist. Tapping, if it could be always safely done, would also be invaluable as an aid. In sarcoma of the kidney, in hydronephrosis, and in pyonephrosis, there are changes in the urine to call attention to them. Those renal tumors at first always have the intestines in front of them; they are not regularly influenced by respiratory movement, nor is their area of dulness on percussion continuous with that of the liver; in hydronephrosis a previous renal colic and possibly frequent discharges of urine followed by diminution in size of the tumor occur. These questions of diagnosis arose in the study of the case of Kocher. He relied much on the results of exploratory puncture, as previously discussed. A connection between the tumor and the uterine appendages and the seat of origin and direction of development of the growth are the points in favor of ovarian tumor; in addition to which, if the fluid be characteristic, the diagnosis of such a tumor would be doubtless correct. A recognition of the various forms of enlargement of the gall-bladder can often be made by attention to the results of palpation and by a consideration of the history of the case. A cancerous tumor of the gall-bladder is fixed, painful, not very large, and is attended by gastric symptoms and cachexia.

Course, Duration, Prognosis.—These all depend upon the cause. Abscess of the gall-bladder is manifested by active symptoms and runs a rapid course. It may terminate favorably by communicating with the exterior, the stomach, the intestines, although long-continued discharge from the fistula might be serious. The prognosis of this condition depends on the direction in which the pus may burrow. Accumulations of bile are serious, on account of the cause of the collection, and the course and prognosis depend upon the concomitant pathological phenomena. Dropsy of the gall-bladder is latent and chronic; the prognosis is not unfavorable.

Treatment.—Tapping of the gall-bladder is no longer performed, for in cases of accumulation of bile, serum, or pus, a surgeon will prefer to open directly into the gall-bladder; purulent collections are practically always to be treated in this manner. At the same time a supporting and stimulating line of treatment must be carried out. The same indications are to be met in accumulations of bile in the gall-bladder as in occlusion of the biliary passages.

Morbid Growths of the Gall-bladder and Gall-duct.—Here and there may be found an isolated report of a case of polypus, lipoma, fibroma (submucous), myxoma, or tuberculosis of the biliary channels, but they are uncommon. Rolleston reports an instance in which a papilloma of the bile duct in intimate association with a stone was removed; some months later the patient returned with a growth in the same region, probably malignant. Bishop[19] described a large, non-malignant, cystic growth of the gall-bladder and cystic duct. The epithelial lining of the cavities was regularly formed and no sign of cancerous formation could be detected. Kelynack[20] has collected instances of fibroma, myxoma, adenoma, and papilloma, though he considers most of the latter to have been epitheliomata. Futcher[21] describes an instance of chronic jaundice due to xanthelasmata in the bile ducts. Primary cancer is more frequent than is generally supposed, the secondary form is very common. Musser (Sr.) has tabulated seventy-eight cases of primary cancer of the gall-bladder, and ten cases of cancer of the bile-ducts. Kelynack among 4,278 cases of cancer finds 8 instances of the former and 2 of the latter. Fütterer (1897) and Rolleston[22] have reviewed this question.

Primary Cancer of the Gall-bladder (Musser)[23].—*Etiology.*—The *age* was not recorded in 8 cases. Two cases occurred under thirty; 13 between forty and fifty; 19 between fifty and sixty; 14 between sixty and seventy; 13 between seventy and eighty, and 1 in a patient over eighty years of age. The variety of carcinoma was not recorded in 28 instances. In the remainder, at no period of life was there any remarkable tendency to one variety rather than to another. The extreme age at which the growths were found is noteworthy. The *sex* was recorded in 75 cases of which 61 were in females and 14 in males. The varieties were equally distributed among the men. Among the women, 18 had encephaloid, 8 scirrhus, 6 epithelioma, 5 colloid, and 2 villous carcinomata; 2 others had sarcomata. Occupation, heredity, and habits played no part in the etiology. Nor did previous health, mental states, or accidents in any way predispose to the disease. Four cases were recorded with antecedent history of gallstones. In the reports of the autopsies, however, it is noted that in 52 of the 78 cases gallstones were found. Kelynack's article[20] includes the most valuable collections of cases up to this time; very complete statistical reports are given. Fütterer in 1900 had collected 268 cases.

Symptoms.—Jaundice was present in 51 of 78 cases. It developed rapidly in 1, was slight in 6, recurring in

1, and continued for periods varying from one week to three months. The cancerous cachexia was observed in 12 cases. Pain was present in 39 instances. It was seated in the right hypochondrium in 22 cases. Nine suffered from epigastric pain. It was described as colicky (8 cases), as lancinating, as paroxysmal, as wandering, as constant, and as severe. Tenderness on pressure was elicited in a few instances. Fever was present in a large number, viz., in 13 cases; it was intermittent in 2, continued in the others.

The gastrointestinal symptoms were marked. Nausea was noted in 5 cases, and vomiting in 30. The appetite was lost in 14; constipation was present in 19 cases, diarrhea in 11. Ascites developed in 16 cases; edema, appearing late in the disease, in 9. Exhaustion ensued in 15; emaciation continued and became excessive in 36 instances. Hemorrhages occurred late in the disease in 5 cases, and grave cerebral symptoms in 7. Physical signs: A tumor was observed in 34 instances; hard and firm, 19 times; irregular and nodular, 8; round, oval, pyriform, cylindrical, and smooth, were the terms used to describe it. In 8 it was movable, in 6 fixed. It disappeared on pressure in 1 instance. It varied in size from a hazelnut to a child's head. Ten times a record of pain in the tumor was made; 4 times the tenderness was marked. The tumor was said to be situated in the region of the gall-bladder (10), in the umbilical region (7), in the right hypochondrium (10), or in close proximity to these situations. The liver was enlarged (21), atrophied (1), hard (2), irregular (2), nodular (3), or tender (2). The veins over the surface were enlarged in 2 instances.

In fine, emaciation, jaundice, cachexia, pain in the region of the gall-bladder, with fever, nausea, vomiting, and loss of appetite, with or without diarrhea, are the prominent symptoms of cancer of the gall-bladder. To corroborate the surmise of its presence, a tumor in the right hypochondrium, tender on pressure, and the seat of pain, and nodular in character, would usually be found. (Musser.[23])

Morbid Anatomy.—The encephaloid variety is found most frequently, the scirrhous next, and then the epitheliomatous, colloid, and villous. Kelynack gives epitheliomatous growths the first place in order of frequency, with scirrhous next. The growth begins at the junction of the cystic duct with the bladder and involves the entire organ, leaving scarcely a trace of it, or infiltrates the coats and encroaches on the cavity. Again, a few nodules are seen underneath the mucous membrane, or a dense thickening of the walls, caused by new formations, takes place, especially at the cystic duct, or finally the gall-bladder is represented by a nodular mass. The mucous membrane is destroyed entirely or ulcerated at various points over the cancer, or is the seat of intense inflammation. Fungoid cauliflower or villous excrescences grow into the cavity of the bladder, or the surface of the mass may be covered with papillæ with bulbous extremities. The tumor may be dense, firm, without juice, or a soft, pulpy mass. In some instances the gall-bladder is reduced in size, very often it is enlarged, even enormously distended. The peritoneal investment is intimately adherent and thickened; subperitoneal nodules are seen, or the external surface in the colloid variety partakes of its peculiar characters. Adhesions are formed between the diseased gall-bladder and the adjacent organs; degeneration of the walls, and at times rupture, take place. Ulceration and perforation are very common. Fistulous communication is thus established between the gall-bladder and the duodenum, the colon, or the stomach. In the course of the disease gallstones are often discharged in this way. The center of the carcinomatous mass is made up of soft, pulpy detritus, or of a thick, creamy matter. In it gallstones are also found, sometimes firmly encapsulated by the growth; or, if the cavity of the gall-bladder remains, it is filled with calculi, with pus, bile, blood, or mucus, singly or combined. In 52 instances out of 78, gallstones were present. The new formation spreads to contiguous structures—thus the liver, colon, stomach, etc., may be involved. Changes are found in the liver and in the ducts, due to obstruction of the large bile ducts. (See Sections on Purulent Inflammation and on Stenosis, for description.) Peritonitis (local) is usually present; an acute inflammation is set up by rupture. Secondary deposits may also be found in the abdominal lymphatic glands, the omentum, the suprarenal bodies, and the pleura.

Diagnosis.—The marked symptoms detailed in the clinical history are to be borne in mind. The character of the tumor, its seat, its mode of growth, its immobility, pain, and tenderness, are important. The occurrence of jaundice and vomiting, the passage of calculi (by a fistula leading to the colon) per rectum, without relief to obstruction, and the occurrence of emaciation, make a diagnosis almost positive. The age and the sex are important factors, and a history of the jaundice is of aid in the diagnosis.

Relation of Gallstones to Carcinoma.—This is believed to be causal. The frequent occurrence of this disease in the same sex in which biliary calculi are most common, is strong evidence. But a case of Quetsch's[24] confirms this opinion more decidedly than does any previous clinical evidence. The patient, a female, was subject to biliary calculi, and a biliary cutaneous fistula had been formed. Subsequently, a carcinoma of the gall-bladder developed in the presence of the calculi which did not pass, and, no doubt, were the cause of the local irritation. Zenker found gallstones in eighty-five per cent. of cases of cancer of the gall-bladder. Similarly high percentages were found by Musser, Courvoisier, Brodowski, Gayle, Bertrand, and others; Siegert, in ninety-five per cent. of primary carcinomas of the gall-bladder, found stones associated, but in only fifteen to sixteen per cent. of secondary carcinomas was this the case. In four cases of primary carcinoma of the liver, reported by Beadles, stones were also present, while none were seen in thirty-six secondary hepatic carcinomatous growths. Slade[25] found carcinoma of the gall-bladder in ten of seventeen cases of gallstones dying from the effects of the stones; the malignancy was only evident under the microscope. In 333 cases of gallstones in the post-mortem records of Guy's hospital there were forty-five cases of carcinoma of gall-bladder or ducts (Ticehurst quoted by Hale White[26]). Others believe that the calculi develop secondarily from stagnation of the bile and precipitation of its constituents.

Duration.—This has been placed at several years by Villard; in other cases death occurred within three months after the first symptoms developed.

The *prophylactic treatment* consists in the removal of or the prevention of formation of, the calculi, and the *treatment* of the disease, after it is once manifested, is purely symptomatic. Robson, however, has removed the gall-bladder and part of the liver in five cases, with more or less encouraging results in four of them. As one of the cases was shown at operation to be a chronic inflammatory condition of ducts, gall-bladder, and adjoining viscera instead of carcinoma, the value of an exploratory operation is certainly suggested.

Primary Cancer of the Gall-ducts.—It may develop within the liver or in the larger ducts. The most common point of origin is at the mouth of the common duct or at the junction of the cystic and hepatic ducts. A firm mass of newly formed tissue surrounds the duct or invades its walls. The lumen is almost or completely obliterated; its inner surface is the seat of ulceration, at certain points, or of papillary growths. A fungous growth projected from the mouth of the common duct in a case reported by Stokes. The anatomical changes of occlusion and stenosis are seen in the liver and ducts. Secondary deposits are found generally in the liver only, along the ducts. Kely-

nack[20] discusses primary cancer of the ducts and has collected twenty-six cases. A diffuse growth was most frequently met with postmortem. Edes[27] and Rolleston[28] are more recent contributors to the subject, dealing particularly with cancer of the extreme end of the common bile duct. Halsted[29] has removed a columnar-celled carcinoma from the ampulla of Vater.

The symptoms common to carcinoma and to biliary obstruction are present. Rarely is the growth large enough to be recognized by palpation. Death is rapid and due to occlusion of the ducts, leading to bile intoxication or purulent inflammation.

Congenital Defects.—The gall-bladder may be absent entirely, without serious inconvenience; a shrivelled pouch or a contracted tube takes its place. In atresia of the ducts, jaundice, umbilical hemorrhage, and marasmus are present during life. The jaundice is present at birth, or makes its appearance a few days afterward, persists, and deepens. The stools show an absence of bile; the urine is bile-tinged. There is from the first a tendency to hemorrhages, and with this ecchymoses under the skin and bleedings from the mouth, nose, or bowels take place.

Umbilical hemorrhage, occurring after the separation of the cord, is especially marked. As the child grows older it loses in flesh, becomes extremely weakened, and dies of cholemia or exhaustion, in spite of an ability to take much nourishment. At first the liver is normal, but if the child lives it becomes very large, and the spleen is likewise increased in size. Ascites may develop. If hemorrhages do not occur the child lives many months. In a case reported by Lotze, the child lived seven months.

R. Lomer[30] reports a curious case. It was one of congenital obliteration of the right hepatic and the cystic ducts. The whole right lobe had undergone cystic degeneration and was shrunken, the gall-bladder was obliterated, but the left lobe remained normal. He analyzes a series of cases, and, from the fact that usually the parents are syphilitic and several of their children are similarly diseased, he holds that an intrauterine hepatitis of syphilitic origin is the cause of the disease. This is the usually accepted explanation of the pathology of congenital disease of the ducts. The obstruction, which is fibrous, may be in a main duct or in one of its branches. The gall-bladder may be normal, but contains a serous fluid. It may be obliterated or remain as a fibrous cord. The ducts in the liver may be dilated, or some may appear like fibrous cords. Sometimes the portal fissure is the seat of local perihepatitis, and usually the surface of the liver is involved. The liver is icteric, the seat of connective-tissue overgrowth, or atrophied. Some parts become cystic. Rolleston and Hayne[31] describe a congenital obliteration of the bile ducts giving rise to an advanced hepatic cirrhosis; Thompson[1] has collected fifty such cases. Ford[32] gives cases of congenital obstruction producing the so-called biliary cirrhosis. An article by Howard and Wolbach[33] should be consulted for recent literature and theories on the subject.

The jaundice due to congenital defects of the ducts is to be distinguished from that jaundice-like discoloration of the integuments, conjunctiva, etc. that is physiological. In this condition, which is common in new-born infants, bile is present in the stools. Jaundice of the simple catarrhal variety also occurs in infants. It usually responds promptly to treatment, and has not the malignant aspect of disease dependent upon deficiency of the ducts. Then, again, a pylephlebitis occurs sometimes in infants. In this case fever and the usual evidences of pyemia are present.

Parasites.—They may develop within the biliary passages (distoma), they may emigrate from the intestines (round worm, psorosperms), or they may find their way into the ducts by ulcerative action (echinococcus). Rarely, the latter develop within the ducts.

1. *Distomum hepaticum (large liver fluke); Distomum lanceolatum (small liver fluke).*—Common in sheep and cows, rare in man. The large fluke is found in the gall-bladder or large bile-ducts; the small one generally in the finer ducts. Both species may occur in the same subject. The latter variety produces the most notable changes in the liver. *Distomum sinense (lanceolatum)* is a common parasite of human beings in Japan, China, India, and the East.

The presence of these parasites sets up a chronic catarrhal and suppurative inflammation of the ducts. Enlargement of the gall-bladder and ducts occurs secondarily. A fibrous inflammation of the walls takes place, with secondary calcareous degeneration of the products of inflammation; the ducts become much enlarged and thickened, and the lumen is dilated. Occlusion of the ducts results on account of the inflammatory disease and the presence of the parasites in the canal. By necessity, therefore, we have the symptoms, previously noted in this section, of the above anatomical changes, and of obstructive jaundice. In addition, nervous symptoms of a reflex nature—as syncope, convulsions, or aphonia—may be present. A positive diagnosis can be made only by finding the parasites in the vomited matter, or in the feces. Death occurs sometimes on account of the inflammatory complications, or from exhaustion.

2. *Round Worms (Ascaris lumbricoides).*—They usually wander from the intestines, and are found with their head toward the liver. Rarely, after adhesive inflammation and fistulous communication between the gall-bladder or ducts and the intestine, worms are found in the biliary passages. The number of them varies—from one to three or four, usually. They are often found alive on making an autopsy, or have died before the death of the patient, and are soft and macerated. Their presence excites catarrhal inflammation, causes occlusion and, secondarily, a purulent cholangitis, a dilatation of the ducts, and subsequent atrophy of the liver, or the formation of multiple abscesses. When limited to the gall-bladder, they cause enlargement and inflammation of that organ. The dilatation of the ducts is usually general; sometimes local sacculated dilatations are observed, in which worms lie rolled up.

The symptoms—if the worm has recently migrated into a duct—are like those of hepatic colic. Later, the symptoms and signs of obstructive jaundice occur, and then those of purulent cholangitis. A history of an attack of worms, the presence of the parasite in the ejecta, and the age of the patient furnish valuable corroborative evidence. Further, intestinal and nervous symptoms due to worms are said to be present. Invasion of the liver by psorosperms (psorospermosis) is rare, but twenty cases were reported in 1898 (McFarlane[34]). The symptoms are those due in general to infections and obstructions of the ducts. The coccidial parasites are taken in with the food.

Echinococcus (Hydatid Disease of the Bile-ducts).—Either an hydatid cyst may press upon one or more of the ducts, causing occlusion of them, or complete obliteration of their lumen, or entire destruction their (Leroux); or the sac may ulcerate into the ducts or bladder, and the vesicles pass by this route into the intestines, with symptoms of hepatic colic; or, finally, it may cause occlusion, dilatation, and inflammation of the biliary passages. This process may terminate in suppuration and gangrene of the cyst, and is usually fatal. The symptoms of obstructive jaundice of a high degree, and of the local inflammatory changes, indicate this pathological condition The presence of hydatid hooklets in the ejecta from the stomach or bowels, a previous history of a painless enlargement of the liver, and the results of exploratory operation would confirm one's opinion of the pres-

ence of hydatid disease. Finally, the gall-ducts are seriously invaded in that rare manifestation of hydatid disease known as multilocular echinococcus. In this instance the walls of the ducts are thickened, hard, and rigid and the lumen is effaced by the presence of the vesicles in the tissues. Secondary inflammation, suppuration, dilatation, etc., may arise in these cases. The symptoms of this manifestation have been considered in the section on Occlusion of the Ducts.

Santonin may be given for round worms. If signs of infection of the ducts arise they should be cut down upon and drained. NORMAN B. GWYN.

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Gallic Acid.—By exposure, to the atmosphere, of galls in the presence of water, chemical conversion of the tannic acid of the galls takes place, resulting in the formation of gallic acid, $C_6H_2(OH)_3.COOH+H_2O$. This body is official in the United States Pharmacopœia under the title *Acidum Gallicum*, Gallic Acid, and presents itself as "white, or pale fawn-colored, silky, interlaced needles, or triclinic prisms; odorless; having an astringent and slightly acidulous taste; permanent in the air. Soluble in 83.7 parts of water, and in 4.14 parts of alcohol at 25° C. (77° F.); in 3 parts of boiling water, and in 1 part of boiling alcohol; also soluble in 40 parts of ether, and in 12 parts of glycerin; very slightly soluble in chloroform, benzene or petroleum benzin" (U. S. P.). On heating, the acid first loses its water of crystallization, then melts, and finally is decomposed, and consumed without residue.

Gallic acid is purely but feebly astringent, and seems practically devoid of any other physiological property. Taken internally, it does not poison, or constipate, or even disorder the stomach unless in excessive dosage. It does not coagulate albumin, and so, when swallowed, is readily absorbed. After absorption it appears speedily in the urine, as is demonstrable by chemical tests. *Therapeutically*, the only reputation of gallic acid is for internal giving for the control of hemorrhages from inaccessible parts—for which purpose the efficacy of the medicine is esteemed very differently by different practitioners. Full and frequent doses are required for this purpose. Gallic acid has been given without untoward effect in dosage of 0.65 gram (gr. x.) every three hours, unremittingly, for three weeks. It has also been used to check the night-sweats of phthisis; but evidence of real value is lacking. The pharmacopœial dose is one gram (15 gr). It may be prescribed in pill, powder, or mixture. Locally, it has been applied in the form of ointment in cases of external hemorrhoids. Gallic acid is incompatible with spiritus ætheris nitrosi and with the salts of iron.

EDWARD CURTIS.
R. J. E. SCOTT.

Gallicin, $C_6H_2(OH)_3COO.CH_3$, or gallic acid methyl ester, is prepared by heating a methyl alcohol solution of gallic acid with strong sulphuric acid. It crystallizes in rhombic prisms or fine needles, which are freely soluble in water and alcohol. It is used as an antiseptic, non-toxic dusting powder, and, in solution, in conjunctivitis. W. A. BASTEDO.
R. J. E. SCOTT.

Gallinipper.—A name often given to mosquitos in some parts of America. See *Insects, Parasitic.*

Gallobromol—dibromogallic acid $[C_6Br_2(OH)_3COOH]$—is a bromine substitution product of gallic acid. It occurs as white crystalline needles or a light brown powder, and is readily soluble in alcohol, ether, and boiling water, but is sparingly soluble in cold water. It has been used as a nerve sedative in epilepsy and chorea, and also locally as an astringent and antiseptic in eczema and other skin diseases. It has also been used as an injection in (strength of one to four per cent.) in gonorrhea and cystitis. W. A. BASTEDO.
R. J. E. SCOTT.

Galton, Sir Francis.—English anthropologist. Born, February 16, 1822. He studied at first with the intention of becoming a practitioner of medicine, but soon abandoned the idea and devoted himself to travel and pursuits of a purely scientific nature. He paid much attention to the subject of finger-prints and to their employment as a means of identifying criminals. He was also greatly interested in eugenics, a term which he was the first to employ (1884). His death occurred in 1911. A. H. B.

Galvani, Luigi.—Born at Bologna, Italy, September 9, 1737. He received the degree of Doctor of Medicine in 1762, and was soon afterward chosen Professor of Anatomy. Although Galvani was chiefly interested in the physical sciences, he devoted himself very conscientiously to the practice of medicine, and was known as an experienced obstetrician and a skilled surgeon. He died December 4, 1798.

In vol. vii. (1791) of the Transactions of the Bologna Institute is printed Galvani's report of his experiments with the electric current upon the nerves and muscles of frogs. In another volume of the same transactions he gives a description of the anatomy of the kidneys and ureters of birds; and in a third volume he reports the results of his investigations into the anatomy of the organ of hearing of birds. He had been working on this subject for three years when it came to his knowledge that Scarpa had already at an earlier date gone over the same field in a most thorough manner, and he accordingly abandoned all further work in this direction. A. H. B.

Gamasidæ.—The beetle mites. In this family of Acarina the skin is leathery, but reinforced by chitinous plates; maxillæ filiform; stigmata lateral; no eyes. Though these mites are most frequently found on insects, *Dermanyssus gallinæ* (the Poultry Mite) and *D. hirundinis* (the Swallow Mite) are sometimes troublesome to man. See *Arachnida.*
A. S. P.

Gamasoidea.—A superfamily of ticks, in which there is a small hypostome without teeth. It includes three families: *Dermanyssidæ*, parasitic on vertebrates, *Uropodidæ*, and *Gamasidæ* or beetle mites. See *Arachnida*.

Gambir.—*Pale Catechu. Terra Japonica.* An extract prepared from the leaves and young shoots of *Ourouparia gambier* (Hunter) Baill. (Fam. *Rubiaceæ*.)

The gambir plant is a native of the East Indies and is a woody vine, climbing by means of stout and sharp hooks. It has recently been introduced to cultivation by the British Government in many of its tropical provinces. The gambir is prepared by boiling the leafy twigs in water and evaporating the decoction. For medicinal use, the decoction is carefully filtered, but much of that used for tanning leather is very coarse and impure, frequently adulterated. The latter occurs in large blocks, or masses, as it is solidified in the containers.

Medicinal gambir occurs mostly in cubes of about an inch square, sometimes in thin cakes. It is of a dull, dirty gray brown color, often streaked with darker brown and with a slightly rough or granular surface. Its fracture is not so brittle as that of catechu, nor is it so porous. The inner color is rather lighter than the outer. It is of low specific gravity. Under the microscope, it shows numerous fine needle-shaped crytals. Tissue fragments should be few and small, if any. It should yield less than five per cent. of ash if of first quality. It is mostly soluble in cold water and almost wholly so in alcohol, the solution being clear. With hot water the solution is turbid. It is nearly odorless and of a sweetish and very astringent taste. Its composition is almost identical with that of catechu. From one-fourth to one-third of it is catechutannic acid and there is rather less of catechin. It is less subject to adulteration than catechu. Its properties are those of a pure coagulating astringent and its uses and dosage are exactly the same as those of catechu. HENRY H. RUSBY.

Gamboge. See *Cambogia*.

Ganglion.—See *Bursitis*.

Gangosa.—The feminine form of a Spanish adjective meaning "nasal-voiced." This word has been erroneously used as a name for the disease *Rhinopharyngitis mutilans, q.v.* J. F. L.

Gangrene.—The term gangrene, and its synonyms, mortification and sphacelus, are employed by the surgeon to denote the death and, in most cases, the subsequent decomposition of a circumscribed portion of tissue on some exposed part of the body. Necrosis is a term extensively used by surgeons to denote the death of a circumscribed portion of bone, while pathologists employ it to express the death of a portion of tissue, belonging to some internal organ, that has been cut off from its necessary blood supply. Such necrosis is unaccompanied by bacterial decomposition; it is absorbed and replaced by the formation of blood-vessels and new tissue.

Mortification is a term used by lay people referring to gangrene. Slough and sloughing are terms applied to dead masses of tissue which form during ulceration or severe inflammation as in abscess or the core in a boil. A dark slough is often referred to as a process of gangrenous sloughing.

Mummification or anthraconecrosis is synonymous with the term gangrene. Mummification is often observed in the gangrene of the aged.

Ulceration is molecular death and it occurs in an open suppurating process.

Necrobiosis occurs in tissues of low vitality and poorly nourished ending in local death of the part.

ETIOLOGY AND PATHOLOGY.—A general division of the causes of gangrene into traumatic, physical, and infectious may be made, but it is evident that, whether the local death of a part is produced by mechanical violence or by other causes, the result must be the same—namely, an interference or arrest of the nutrition of the part due to obstruction of the circulation. Nutrition is interfered with, or arrested, by *obstruction in the arteries*, such as occurs in cases of gunshot wounds; by ruptures due to mechanical violence; by compression of ligature; by disease of the arterial coats; by pressure of a tumor in the adjacent tissues, or by a thrombus; by *obstruction in the capillaries*, which may produce complete anemia of the part, and which is due to pressure upon the capillary walls by tumors, by extravasated blood or fibrin, or by superficial pressure from bandaging. The observation that tight bandaging would occasionally produce gangrene is as old as Hippocrates, who distinctly refers to it. Anything, therefore, which will produce long-continued stasis in the capillary circulation of a part—whether it be mechanical violence, inflammatory change, the internal administration of certain drugs, the action of chemicals, or some obstruction in the veins sufficiently pronounced to prevent completely the return circulation—must necessarily result in gangrene of that part.

Let us now examine these causative states somewhat in detail. Obstruction to the arterial circulation occurs in consequence of gunshot, lacerated, and incised wounds, whenever the artery is torn or cut, and this obstruction results in gangrene whenever the collateral circulation fails to become established. Plate XXXVI., FIG. 2, and Plate XXXVII., from the "Medical and Surgical History of the War of the Rebellion," show cases of this kind with great distinctness. Pressure upon arteries during the treatment for aneurysm has also produced gangrene. Surgeon Fessenden, of the Marine Hospital Service, has reported a case (U. S. Marine Hospital Reports, 1882, pp. 160–162.) in which compression was applied to the popliteal artery, just above an aneurysm of that vessel, for one hour, when pulsation ceased in the tumor; three days later, it was noticed that sensibility was lost in the foot and leg, which became very much discolored, and there occurred blebs on the foot; a day later the entire foot and leg were gangrenous, and amputation was performed.

Coagula (thrombi) may form in the arteries as a result of chronic endocarditis or endarteritis. Obstruction to the capillaries is a prolific source of gangrene. It is in them that the effect of diminished cardiac power is most manifest, especially in the parts remote from the heart. Chronic exhaustive diseases, senile and general debility, therefore, are important factors in the production of gangrene. Gangrene from the administration of ergot is produced by the effect of the drug on the arterioles through the vasomotor nerves, whereby these vessels are permanently diminished in caliber. The experiments of Holmes (1870) showed the effect of ergot upon animals to be manifested in the capillaries, as witnessed in frogs, and Péton (1878) observed the contraction of the retinal vessels in man. Péton believes that this effect is produced, independently of any influence upon the vasomotor system, by the direct action of the drug upon the muscular fibers. Nikit, however, in 1878, denied this, and his investigations have led him to confirm the usually accepted theory. In recent years we have learned to distinguish some infectious causes of gangrene, and also to recognize the fact that carbolic-acid solutions are, in certain cases, competent to induce this condition. Farther on, we will consider these matters more in detail.

Ergotism, as a cause of certain epidemics of gangrene in man, was first described by Dodard in 1676, then by Saviard in 1694, and by Noel in 1710. The disease appeared in Switzerland in 1676, according to Langius and Quassond. It also appeared in Dauphiné in 1709. Duhamel, in the "Mémoires

de l'Académie Royale de Paris" for 1748, states that the disease was accompanied by very great mortality, "not more than four or five out of one hundred and twenty who had been attacked escaped with life."

Péreira (1840) thinks that this affection was known at a still earlier period, and he quotes a passage from Sigebert to support his views (South): "1089, a pestilential year, especially in the western parts of Loraine, where many persons become putrid in consequence of their inward parts being consumed by St. Anthony's fire. Their limbs were rotten and became coal-black, they either perished miserably or, deprived of their hands and feet, were reserved for a more miserable life." It is stated that "the bread which was eaten at this period was remarkable for its deep violet color."

Notwithstanding the general concurrence of opinion as to the effects of ergotism on man, it has often been denied that it produced any such effect upon animals. Block, in 1811, fed nine pounds of ergot daily to twenty sheep for four weeks without any visible effect, and twenty sheep of another lot ate thirteen and a half pounds daily for two months without injury. Thirty cows took twenty-seven pounds daily for three months, and the only apparent effect was to injure the quality of the cream (Péreira). Tessier, however, in 1776, visited those countries in which the epidemic had prevailed, or was then present, and found that, although the quantity necessarily varied, yet it finally produced the gangrenous affection ("Mémoires de la Société Royale de Médicine, "1776, 1777–78). Instances are not wanting of the prevalence of gangrene as an epidemic among animals in the United States. Dr. Salmon, Chief of the Bureau of Animal Industry of the Agricultural Department, in a report on this subject (1885) showed conclusively that many so-called epidemics of the foot-and-mouth disease of cattle are really epidemics of ergotism. He found much ergot in the heads of "red-top" grass, in timothy, and in the chess or "cheat," as well as in rye; and in the particular epidemic in Kansas which called out the inquiry, the ergot was found in the hay fed to the diseased animals in the proportion of about one to every seventy-five pounds. In these cases there were sloughing ulcers of the mouth, ulcers in the rectum, with diarrhea, a temperature of 101° to 104° F., and a line of demarcation above the hoof in some cases as high as the middle of the leg, and not infrequently the ends of the tails became gangrenous and dropped off. In an exhaustive review of the history of epidemics of gangrene from ergotism, Dr. Salmon cites many instances to show that nearly all the domesticated animals have suffered from the effects of this poison. As bearing upon the question of treatment, it is interesting to note that Dr. Salmon considers that ergot in hay may be prevented by cutting the grass before the seeds have formed.

The first effect of extreme cold upon the tissues is the contraction of the capillaries to the smallest practicable degree. A certain amount of blood serum is actually frozen and the capillary is ruptured, the circulation is not resumed when the parts are thawed, and gangrene results. Gangrene thus produced is usually of the dry variety, although, when the venules or the larger venous trunks are frozen, by reason of the failure of the return circulation, moist gangrene is produced. Direct destruction of cells by caustic chemicals may produce gangrene of distal parts through failure of both supply and return of blood. Gangrene of the perineum may occur from extravasated urine (Green, 1884), as even normal urine is highly irritating; but in such cases there must have been local inflammation and consequent death of the adjacent cells. Urine which has undergone putrefaction, being loaded with the putrefactive bacteria, is often very speedy in its action, especially as the tissues themselves are weak in their power of resistance; while not absolutely devitalized, they are yet in a state of extreme inertia. It is well known that the power of resistance to the entrance and subsequent development of the pathogenic bacteria is variable, and that, for instance, in cases of convalescence from such exhaustive diseases as typhoid, typhus, and the severer exanthemata, fatal forms of so-called blood-poisoning are apt to make their appearance; this condition, while perhaps immediately dependent upon diminished cardiac power, is one of deficient innervation; for insufficient nutrition of the nerve centers is necessarily manifested in weakness of muscular tissues throughout the body.

Obstruction of the veins, it will be seen, is very rarely a direct cause of gangrene; pressure or occlusion of the superficial veins alone will scarcely produce it, unless there is constitutional predisposition, as above set forth, for the deep veins will still carry away a large share of the return blood current. When gangrene does result from compression or ligature of superficial veins, it is by the production of stasis in the capillaries; to this cause we must refer the cases produced by tight bandaging, and, indeed, all of similar character, except those of venous thrombi.

Moist Gangrene.—This form of gangrene, also called acute gangrene, hot gangrene, inflammatory gangrene, is always preceded by inflammation. The part is at first swollen and painful, there is almost always inflammation of the veins (phlebitis), and the moist condition depends upon the construction to the return circulation, by which the water is left in the tissues.

Dry Gangrene.—In this form of gangrene there is neither venous obstruction not failure of the lymphatics, and the fluids of the part are carried back into the system as fast as formed. As the arterial supply is gradually cut off, a drying or mummification of the tissues results. This condition frequently occurs in those who are suffering from starvation or who are subject to gout (Chelius); it also occurs in those who have exhausted themselves by excessive debauchery. There is frequently an absence of inflammatory symptoms, and the gangrene may develop suddenly without premonition. There is usually organic disease of the heart and arteries. This is the chronic gangrene of Travers (South).

Senile Gangrene.—This gangrene, which is usually of the dry variety, is almost wholly due to arterial obstruction, the pathology of which has already been discussed; but the obstruction is long in forming, and the progress of the disease is slow. The description which Percival Pott gave of the affection, as it occurs in the foot, was so striking that for a long time it was known as Pott's disease of the toe; but, as the disease occasionally attacks the hands, the name was manifestly inappropriate. The condition of the arteries in these cases is one of "ossification," or, rather of calcification, which results in a complete loss of elasticity of their walls, and consequent diminution of the blood supply. The bead-like feel of the radial pulse, in the aged, gives the observer a palpable object-lesson in senile calcification. The statement has been made that certain seasons specially predispose to senile gangrene, and the winter is alleged to be the season most favorable to its production owing to the astringent effect of the cold; but there are no statistics to bear out this assertion, and the writer considers the case by no means made out.

Symptoms.—After some months or weeks of pain or otherwise unpleasant sensations in the part, a small bluish spot appears on one of the toes, frequently at the root of the nail, and the spot becomes black; from this point the discoloration slowly spreads to the adjoining toes, and finally, if the patient survive long enough, the whole foot and leg become involved. Sometimes the line of demarcation is formed near the center of the foot, but more often the patient suc-

FIGS. 1 AND 3. SHOWING EFFECTS OF HOSPITAL GANGRENE.
FIG. 2. GANGRENE OF FOOT AFTER SHOTWOUND OF LEG.
(FROM THE MEDICAL AND SURGICAL HISTORY OF THE WAR OF THE REBELLION.)

cumbs under the combined influence of the nervous exhaustion produced by the pain and the failure of the digestion. The pain accompanying the disease is a prominent symptom, and gives the patient more immediate concern than the fear of losing the limb, or even life itself. The accompanying figure, taken from the photograph of a patient under the care of Dr. John B. Hamilton, at the Providence Hospital, shows the stage of the disease at the time of her death. The notes are as follows: Elizabeth B———, aged eighty-five, admitted to hospital April 13, for a contusion of the knee, which, however, had left no trace; the pain in the toes and foot had been constant and harassing. Three weeks later, a blue spot was noticed on the dorsum of the second toe. The spot gradually spread until it included the great toe as shown in the photograph, and the patient died July 20, 1885.

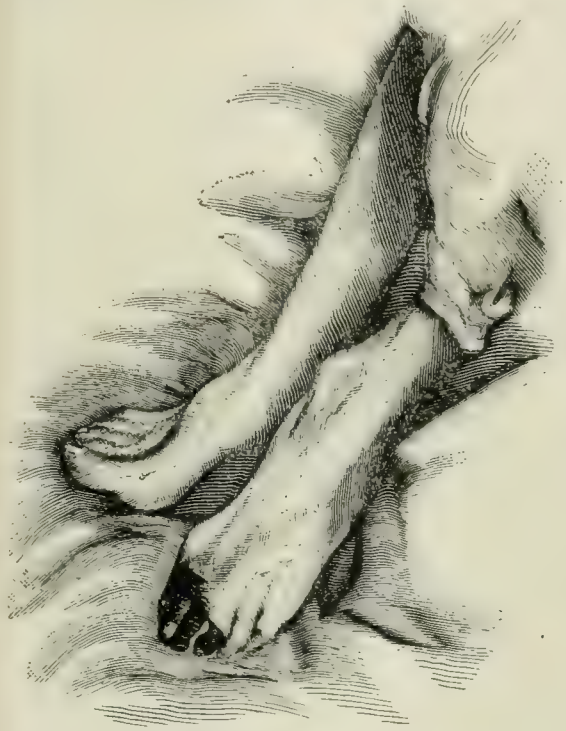

Fig. 2683.—Dr. Hamilton's Case of Senile Gangrene.

Treatment.—This has been well formulated by Van Buren. "The treatment of senile gangrene is limited to a judicious husbanding of the patient's vital resources, looking to a possible self-limitation of the disease, after which a cure may be completed by amputation." To husband the patient's resources it is necessary, along with stimulating and supporting measures, to control the pain. In these cases, as in the foregoing varieties of gangrene, external heat will be found advantageous.

In a case of a toe that is dead or undergoing death from senile gangrene, the indication is to prevent infection. To this end wet dressings should be avoided and reliance should preferably be placed upon dry antiseptic dressings like boric acid powder on dry cotton loosely applied to permit evaporation. Amputation should be deferred until the toe becomes loose enough to be removed by slight torsion with forceps. It is better to do this than operate too soon when there is danger of extension of the gangrenous process which often requires a more extensive amputation.

If the gangrenous process has invaded the dorsum or sole of the foot the trunk should be amputated above or just below the knee according to circumstances, and great care should be exercised in the use of antiseptic details and unnecessary traumatism to the tissues.

Spontaneous non-senile, or presenile gangrene are terms used in connection with gangrene that occasionally develops in young or middle aged subjects. Its etiology, clinical history and treatment are the same as the senile form.

Raynaud's Disease, Symmetrical Gangrene.—This affection, probably first accurately described by Raynaud ("De l'Asphyxie locale et de la Gangrène symmétrique des Extrémities," 1862), is exceedingly rare. According to Raynaud, the disease occurs chiefly in chlorotic and nervous individuals of early adult life, patients in convalescence from typhoid fever and similar exhausting disease. Moore ("International Encyclopedia of Surgery") has seen a case presumably dependent upon this cause, and the appearance of the parts affected is shown in the plate which accompanies the doctor's article.

"The disease most frequently attacks the fingers—rarely the toes, tip of the nose, and external ear; often, for months beforehand, the affected parts suddenly become while, bloodless, without feeling, dead; the skin is strongly wrinkled and shrunken, the ends of the fingers appear thin and conical. The temperature of the parts is sunken, and the muscular movement is as though paralyzed. If this state extend over a whole extremity, the pulse becomes imperceptible. After a variable time there follows a painful reaction; itching arises, and the feeling of overfilling of blood; the skin becomes bluish-red. Severe pains precede the proper outbreak of gangrene. The extremities become bluish-white, violet, dark, livid, marbled; they are insensible but very painful, and icy cold; then small vesicles appear which fill with seropurulent liquid, and are usually destroyed, so that the cutis becomes laid bare. Even now, the part may be restored; but for the most part, after a time the attack returns, and then the fingers show numerous small, white, depressed, and hard cicatrices on their extremities, which are found especially in front of and beneath the nails, and form conical callosities. If the ischemia is of longer duration, there follows from the consecutive hyperemia a true mummification, which terminates with the falling-off of the last phalanx" (Wagner).

According to recent investigations with the Roentgen ray Raynaud's disease, or symmetric gangrene as it is called is associated with certain bone changes (Carl Beck). It is also suspected that Raynaud's disease has not infrequently been confounded with senile, presenile, or diabetic gangrene. The cases of Raynaud's disease in which absence of vascular changes cannot be demonstrated are becoming infrequent. We know also, that symmetric nodular arteriosclerosis is much more common in the young than was formerly supposed. Again, the early clinical history of Raynaud's disease and that of senile and presenile gangrene is very much the same.

The *treatment* is the same as that employed in senile gangrene.

Diabetic gangrene is a misnomer. It was formerly thought that diabetes mellitus caused gangrene but the occurrence of gangrene in diabetics is (*a*) always associated with the senile and presenile condition of the arteries; (*b*) it is probably more correct to state that the disease favors nodular arteriosclerosis, and that the sugar in the tissues particularly promotes the growth of microorganisms; (*c*) the tissues of a diabetic subject having poor resistance are specially susceptible to traumatisms and mortification from microbic invasions.

Symptoms.—The symptoms are quite similar to those of spontaneous, senile, or presenile gangrene. The gangrenous part is prone to infection which spreads rapidly.

Treatment.—The treatment is the same as that recommended for senile gangrene. The usual treatment for diabetics should be pursued unremittingly. Owing to the rapid spread of infection, and the low vitality of the tissues, if the gangrene spreads beyond a toe or a small area with the presence of constitutional symptoms, amputation high up, in the lower third of thigh, should be performed at once. Sutures should not be tied tightly and provision for drainage should be invariably made. To avoid mutilation of the tissues the Esmarch bandage should not be used but digital compression of the main artery should be relied on.

It is preferable to amputate when the amount of sugar is low, and operation should be withheld if acetone bodies exceed 0.02 gram in 50 c.c. of urine, otherwise postoperative coma is apt to supervene (Kelly).

Albumin in the urine adds to the danger of operation. Notwithstanding the objections to the presence of sugar and albumin, they do not absolutely contraindicate operation, since well declared diabetic gangrene is almost invariably fatal without amputation. Sugar and albumin may diminish after operation and they both disappear for a time in a certain percentage of operated cases.

Microbic or traumatic spreading gangrene is a form of gangrene due to different kinds of gas-producing microorganisms. The literature treats of this form of gangrene under a variety of names aside from those above stated, viz., *gaseous gangrene, traumatic emphysema, gangrenous septicemia, acute gangrenous edema, gas phlegmon, gangrenous cellulitis,* etc. Although caused by different microorganisms, clinically, anatomically and histologically, the disease is the same in type. The chief characteristics of the disease are profound toxemia, and the rapid formation of gas in the tissues. The disease is most frequently caused by the *Bacillus aerogenes capsulatus* of Welch and Nutall, but it is at times due to the presence of *Bacterium pseudo-œdematis maligni, Proteus vulgaris,* colon bacillus.

Symptoms.—Gangrene from the gas-producing microbes is prone to occur in wounds exhibiting much laceration, contusion, hematomata and coagulation necrosis, although it occasionally commences in trivial wounds. The colon bacillus grows rapidly in the traumatisms of diabetic subjects when infection takes place. The bacillus aerogenes capsulatus is most frequently associated with compound fractures and next it is most frequently found in gunshot wounds (Shattuck Lectures by Welch). This bacillus is found in the intestinal tract. One of the author's cases developed in an old fistula *in ano,* and its presence was not detected until the time of operation.

Gangrene from gas bacilli spreads rapidly from which it derives its name *gangrène foudroyante* or *lightning gangrene.* In this the infection is seen primarily and not secondarily as in the other forms of gangrene. There is no tendency to a line of demarcation. A whole limb may become involved in one day.

The skin is at first dusky red, then brown and next blackish green; the lymphatic vessels are early involved as shown by red lines running up the limb to adjoining glands which enlarge rapidly. The member becomes very much swollen, and the tissues become filled with the rapidly forming gas which is revealed by crepitation on pressure, and when the skin is incised a dark watery fluid will be liberated containing gas bubbles. Gangrenous connective tissue will be apparent here and there in the incision. The muscles are disintegrated and pulpy from the gangrenous process.

Autopsy shows cloudy swelling of the internal organs. A condition of "foamy organs" is noted if the microorganisms have invaded the blood-vessels after death.

There is profound sepsis as a rule; a weak rapid pulse; subnormal temperature, facies express anxiety, the capillary circulation of the surface is sluggish. Death occurs in fifty per cent. of the cases.

Treatment.—Early and prompt amputation where this can be practised is the only safe rule of treatment. The amputation should be made *through sound tissues.* In parts where amputation cannot be practised, numerous, deep, free incisions to admit air to the tissue should be made. The incised surfaces should be irrigated freely with antiseptic solutions and kept covered by moist dressings. A hot bichloride bath 1 to 6,000 has yielded good results. Nourishing and stimulating food should be given, water should be administered freely per os, and copious injections of physiological salt solution per rectum should be employed several times per day.

Noma.—This is a gangrene affecting the pudenda and cheeks of young children from the age of weaning to that of puberty. Nurslings seem to have an immunity from it. When confined to the cheeks and mouth, it is variously termed *gangrenous stomatitis, gangræna oris, cancrum oris, necrosis, necrosis infantilis, buccal anthrax, water canker, sloughing phagedena* of the mouth, and by the Germans *Noma* and *Wasserkrebs;* by the French *gangrène de la bouche.* The disease has been known for a long period, and was first described by Carolus Battus, of Amsterdam. Van Swieten (1699) recognized the disease as gangrene. Wiseman (1676) mentions the disease as noma, which he describes as "a deep Ulcer that eats and spread without Tumor, but hath a Rottenness and Putrefaction joined with it."

Fig. 2684.—Gangrenous Stomatitis (Noma). (Cabot.)

The disease is attended by great mortality, but as it usually comes on while the patient is suffering from some other affection, it is difficult to determine its relative fatality with precision. The affection, whether it appear on the cheek or on the vulva, is almost invariably unilateral. It begins as an inflammation attended by great exudation, ulceration is set up, the exudate dies, and the general appearances of circumscribed gangrene due to obstruction of the arterioles are present. In the mouth the disease usually begins at the frenum of the lip, but rarely on the outside of the cheek (Chelius), and as the edematous inflammation extends the ulcerative process is carried down to the bone and alongside of the nose, and frequently involves the whole Schneiderian membrane.

Occasionally the disease begins on the gums at the alveolar border (Cohen.) At the pudenda the disease usually commences at the labial margin, and extends to the clitoris, nymphæ, and hymen, and sometimes to the urethra, when the pain on micturition is acute; the inflammation is rapid, and the tissues speedily fall out by sloughing, the disease spreads to the perineum, to the anus, the thigh, and to the mons Veneris, and, as is the case when the disease affects the mouth, the sloughing is deep and frequently extends quite to the bone. Sometimes the affection beginning at the mouth is later on developed at the vulva, and frequently the noma is ushered in with general constitutional symptoms, such as rigors with fever; but more commonly its onset is masked by the particular affection from which the child has been suffering; but always, in the later stage of the affection, there is great prostration, with feeble pulse and chlorotic countenance. When the affection is on the pudenda, there is great pain in all movements of the lower extremities, and the child usually assumes of its own accord the dorsal decubitus, and the legs are widely separated. There are retention of urine, owing to the severity of the urethritis, and constipation. There is rapid emaciation, and the patient sinks under the "typhoid condition" so constantly present in the later stages of the other forms of gangrene. Cohen remarks that in noma of the mouth pulmonary gangrene is often observed as a complication, as is also enterocolitis. When noma affects the mouth alone, there is great variability in the degree of constitutional sympathy, some patients being able to sit up and play, while others are hopelessly comatose from the outset. Hemorrhage from the facial or from the pudendal branches of the pudic may occur; but in this variety, as in other forms of gangrene, the arteries are plugged by septic thrombi long in advance of the loss of tissue. The disease is of microtic origin, although the specific organism causing it has not yet been isolated. Many cocci and bacilli have been found in the sloughs and buccal cavity. Blumer and McFarlane and others have called special attention to a species of leptothrix which is very much like the spirochete of necrosis described by Herman. Some observers have advanced the theory that noma and the hospital gangrene of our Civil War are identical. The appearances and symptoms of the two diseases are quite similar.

Treatment.—The treatment of noma is prophylactic and curative. The mouths of children suffering from infections, especially measles or other debilitating diseases, should be kept specially clean. Any sore or ulcer in the buccal cavity should be promptly cauterized with a stick of nitrate of silver or pure carbolic acid.

When the gangrenous process commences to spread it is to be treated by one of three methods, viz., the disease may be extirpated with a knife; it may be curetted and the surface treated antiseptically; or preferably, it should be burnt out with the actual cautery. Unless the infected area is radically removed until sound tissue is exposed, the disease will continue to spread. Although burning with the cautery sacrifices extensive areas of tissue, the harm done by burning will be far less than that produced by the disease unless it is cut short.

Hospital Gangrene.—This form of gangrene, known also under the various names of *hospital phagedena, gangræna nosocomialis, and pourriture des hôpitaux*, was the scourge of military hospitals in the preantiseptic era. To-day it is absolutely unknown, the vast majority of living surgeons having had no clinical experience with it. Whether its spread was due to the agency of a specific microorganism, or to an acquired virulence of the well-known pathogenic microbes in victims rendered specially susceptible by lowered vital resistance, remains a matter for speculation. Because of its great rarity we must turn to the writings of the older authors for a clinical picture of the disease. Mr. Guthrie graphically describes it as follows: "A wound attacked by hospital gangrene in its most concentrated and active form presents a horrible aspect after the first forty-eight hours. The whole surface has become of a dark-red color, of a ragged appearance, with blood partly coagulated, and apparently half putrid, adhering at every point. The edges are everted, the cuticle separating from half to three-fourths of an inch around, with a concentric circle of inflammation extending an inch or two beyond it; the limb is usually swollen for some distance, of a white, shining color, not peculiarly sensible except in spots, the whole of it being edematous and pasty. The pain is burning and unbearable in the part itself, while the extension of the disease, generally in a circular direction, may be marked from hour to hour; so that in from another twenty-four to forty-eight hours nearly the whole of a calf of a leg, or the muscle of a buttock, or even the wall of the abdomen may disappear, leaving a deep great hollow or hiatus of the most destructive character, exhaling a peculiar stench which can never be mistaken, and spreading with a rapidity quite awful to contemplate. The great nerves and arteries appear to resist its influence longer than the muscular structures, but these at last yield; the largest nerves are destroyed, and the arteries give way, frequently closing the scene, after repeated hemorrhages, by one which proves the last solace of the unfortunate sufferer. . . . .The joints offer little resistance; the capsular and synovial membranes are soon invaded, and the ends of the bones laid bare. The extension of this disease is in the first instance through the cellular structures. The skin is undermined and falls in, or a painful red and soon black patch is perceived at some distance from the original mischief, preparatory to the whole becoming one mass of putridity, while the sufferings of the patient are extreme."

The surface of the wound soon becomes a sticky, pulpy mass of a grayish color. This substance cannot be wiped off, and it resists the usual washings. If, at this stage, the further progress of the disease be not arrested, the patient succumbs, as from a fatal form of septicemia. The disease was very prevalent in the military hospitals of our Civil War; an extended account of it may be found in the surgical volumes of the "Medical and Surgical History of the War of the Rebellion," by Otis (see Plate XXXVI., Figs. 1 and 3).

Treatment.—The treatment should be prophylactic, constitutional, and local. The first of these should have reference to the rules of antiseptic and aseptic wound treatment and to the rules of hygiene that bear on the subject of overcrowding; and when the disease first appears in the wards containing other wounded, it is important promptly to isolate those who are affected. The constitutional treatment should be directed to the free use of stimulants and good nutritious food. The local treatment directed to the gangrene when it invades the wounds should be of the most radical kind. The slouging tissues should be removed by means of the curette and scissors, and the actual cautery should be applied freely. Bromine, fuming nitric acid, and subnitrate of mercury were extensively and successfully used by the older surgeons.

Gangrene in connection with gout, Bright's disease, and syphilis is closely allied to senile and presenile gangrene since the vascular changes are common to both.

Gangrene from Ergot.—This form of gangrene arises from eating bread from spurred rye, as stated above.

The *symptoms* are very much the same as those of senile and other forms of spontaneous gangrene. The pathology with reference to the vascular changes is

also similar. The treatment is the same as that laid down for the senile and allied forms of gangrene.

Gangrene from Frostbite.—This is similar to other forms of mortification. Death of the tissues occurs from direct action of cold on the protoplasm of the cells, and from ischemia due to vascular spasm and thrombosis from a roughening of the intima and deposition of clots either hyaline or fibrous. The mortification of frostbite is quite similar to senile andp resenile gangrene except that the process is acute in frostbite.

Treatment.—The victim of frostbite should be placed in a cool room, and the frozen part should be gently rubbed with snow or cloths wrung out of ice water with due care not to break the skin. There should be a gradual elevation of the temperature of the air in the room and that of the water. If the circulation is restored the limb should be elevated and wrapped in cotton. If mortification sets in, the member should be wrapped in a clean antiseptic dressing to avoid infection. A dry dressing is preferable since it promotes dryness of the tissues which in itself affords protection against microbic invasion. To this end the liberal use of boric acid as a dusting-powder is to be recommended.

Amputation is to be deferred until a line of demarcation has been established. Amputation should be prompt if moist gangrene sets in and commences to spread.

Postfebrile Gangrene.—Mortification will sometimes occur as a complication of typhoid fever and other debilitating diseases like measles, diphtheria, scarlatina, etc. In all such cases the gangrene is the result of obstruction of the blood supply due to thrombosis. It is most frequently noted in the extremities, but it attacks the nose, ears, face, anus, perineum, genitalia and the skin of the trunk.

Treatment consists in prophylactic measures calculated to build up the resistance of the patient. Now that it is proper to feed fever patients, the debilitating influences of prolonged sickness do not end in complications like gangrene as often as formerly.

When gangrene sets in the parts should be wrapped in a dry antiseptic dressing which permits evaporation. Amputation should be deferred until a line of demarcation has been established.

Ainhum.—This is a form of gangrene of unknown origin, more frequently seen in men than in women. It has been met with in the East and West Indies and Brazil, but it is more frequently observed among negroes on the west coast of Africa. The affection is usually limited to the little toe, although it has occasionally been observed in the little finger. It begins by the occurrence, on the plantar surface, of a fissure which encircles the toe near the web. As the fissure deepens, gangrene of the soft parts occurs, with a rarefying osteitis of the bones. The disease is very gradual, the process lasting as much as ten years in some instances. It usually ends in spontaneous amputation.

Carbolic-acid Gangrene.—The watery solutions of this antiseptic drug used in surgical practice have been known to cause gangrene when persistently applied, especially to fingers and toes. The evaporation of the water, in the solution, which takes place during the prolonged application of compresses so saturated, tends to concentrate the agent in the dressings; hence the well-known effects of the strong solutions, such as blanching, numbing, etc., which lead ultimately to gangrene. So many cases of gangrene from this source have been reported in recent medical literature that topical applications of the drug to the parts mentioned should be practised with extreme caution.

Louis A. LaGarde.

Garlic.—Allium.—The bulb of *Allium sativum* L. (Fam. *Liliaceæ*).

Garlic is a compound bulb, globose-ovoid, an inch or two in diameter, of a white or red-brown color and a very strong alliaceous odor and taste. The drug proceeds wholly from cultivated plants.

Garlic contains as its active principle—either already formed or produced, as in mustard, etc., by the addition of water—a very irritating, pungent, and volatile oil, *sulphide of allyl*, similar to that of the onion and others of the genus and belonging to the same group with the oils of mustard and other *Cruciferæ*.

It is now and then given with some advantage, as an antispasmodic, and sometimes as an expectorant in chronic bronchitis and pharyngeal or laryngeal catarrh. Internally taken, garlic, like the onion, etc., is an aromatic and carminative, and scents the breath with sulphur compounds during elimination. Recently, it has been claimed that the free use of garlic has a tendency to inhibit the development of tuberculosis.

The syrup, of twenty-per-cent. strength, should be made from the fresh bulbs. Of this the dose is a half-ounce. The fresh juice is also often given in half-drachm doses. The fresh bulb is sometimes crushed and applied to the chest as a rubefacient.

Henry H. Rusby.

Garrigues, Henry Jacques.—Born in Copenhagen, Denmark, on June 6, 1831. He was graduated in medicine in 1869 from the University of Copenhagen when thirty-eight years old. Six years later, 1875, he came to America and began practice in New York City, where he lived until his retirement from professional work. He died at Tryon, N. C., on July 7, 1913.

Dr. Garrigues' first appointment in New York was as Gynecologist to the German Dispensary in 1879; and in 1881 he became Obstetric Surgeon to the

Fig. 2685.—Henry Jacques Garrigues.

New York Maternity Hospital; he was then successively Attending Physician to the New York Infant Asylum and Gynecologist to the German Hospital, Professor of Obstetrics at the New York Postgraduate Medical School and Hospital, Gynecologist to St. Mark's Hospital, Consulting Surgeon to the New York Maternity Hospital, Professor of Gynecology and Obstetrics in the School of Clinical Medicine, Consulting Physician to the Mother's Home and Maternity Hospital, and Consulting Gynecologist to St. Mark's Hospital. He was a member of many medical societies; in 1901 he was made an Honorary Fellow of the American Gynecological Society, and in 1902 an Honorary Fellow of the Obstetrical Society of Edinburgh.

Dr. Garrigues was not only a prolific writer in the medical journals, but the author of several books,

GANGRENE FOLLOWING A SHOT LACERATION OF THE FEMORAL ARTERY

(FROM THE MEDICAL AND SURGICAL HISTORY OF THE WAR OF THE REBELLION.)

the best known of which are Diagnosis of Ovarian Cysts, published in 1882; Practical Guide to Antiseptic Midwifery, 1886; Text-book of Diseases of Women, 1894, 1897, and 1900; Text-book of Obstetrics, 1902, 1907; Medical and Surgical Gynecology, 1905. In addition he contributed the article on the Development of the Female Genitals and Malformations of the Female Genitals in 1887 to the System of Gynecology by American Authors; and in 1889 he wrote the article on Puerperal Infection and Diseases of the Breasts in the System of Obstetrics.

Up to 1883 puerperal fever was a common occurrence in the obstetric wards of hospitals and the resultant deaths were far too numerous. At this time Dr. Garrigues introduced into the wards of the New York Maternity Hospital a plan of rational antisepsis which has revolutionized the practice of obstetrics and reduced to a minimum the deaths from puerperal fever. In the world of medicine Dr. Garrigues' name stands for the ideal of surgical cleanliness in obstetrical work. E. L. J.

Gas, Illuminating (*Fuel Gas, Coal Gas*).—These names are applied to complex mixtures of gases, made from coal, wood, oils, resin, petroleum, shales, etc., by a process of destructive distillation. The most of these gases contain more or less of the oxides of carbon, especially of CO, and in this country they are the most frequent sources of poisoning by carbon monoxide. Much of what has been said as to the effects of this gas applies to illuminating gas. (See article on *Carbon, Oxides of*.)

Coal gas was first used for house lighting by William Murdock in London in 1792. It was first used for street lighting in London in 1812, and in Paris in 1815. In this country, especially in the larger cities and in some towns, the so-called *water gas* enriched with naphtha has nearly replaced coal gas. The complete apparatus for its preparation consists of: 1. A set of semi-cylindrical iron or clay retorts, set horizontally in a furnace. 2. A series of horizontal and upright iron pipes acting as condensers, in which the liquid products of the distillation are condensed and separated from each other, and from the gases. 3. One or more purifiers, which consist of upright stacks, containing moistened coke, freshly slaked lime, ferric hydroxide, or mixtures of these with sawdust. The object of these purifiers is to absorb the most of the carbon dioxide, sulphureted hydrogen, etc., before the gas is stored for use. 4. A gasometer or gas-holder, which consists of an inverted iron tub of large size floated in a well of water. The gas is conducted into this gasometer by a pipe leading from below and terminating above the water, where it is stored ready for use.

The coal is heated in the retorts to a cherry-red heat, or about 1,500° F. This temperature breaks it up into coke (which remains in the retort), liquid and volatile products, and gases. Ordinary bituminous coals yield about ten thousand cubic feet of rather poor gas per ton. It is a common practice to mix with these coals about five to ten per cent. of a rich boghead or cannel coal, to improve the illuminating power of the gas produced.

Composition.—The gas ordinarily used is a mechanical mixture of various gases, some of which are illuminating agents, while others have no value in this respect, but are combustibles furnishing considerable heat, while there are usually some present which are inert either as combustibles or as illuminants. Besides the true gases, there are present vapors of certain hydrocarbons, which are of value as illuminating agents. The chemical composition of the gas varies with the coal used, and the temperature to which it is subjected. The chief constituents of coal gas, with the quantities of each, are given in the following table from Letheby:

	Volume per cent
1. Hydrogen	25 to 50
2. Marsh gas	35 to 52
3. Condensible hydrocarbons. Olefiant gas (C_2H_4), propylene (C_3H_6), butylene (C_4H_8)	3 to 20
4. Benzol and its series	[illegible]
5. Acetylene (C_2H_2)	[illegible]
6. Naphthalene ($C_{10}H_8$)	[illegible]
7. Carbon dioxide (CO_2)	0 to 2
8. Carbon monoxide (CO)	5 to 9
9. Cyanogen (CN_2)	Traces
10. Ammonia (NH_3)	0 to 0.06
11. Bisulphide of carbon (CS_2)	0.004 to 0.05
12. Aqueous vapor (H_2O)	0.6 to 2.5
13. Oxygen	0 to 10
14. Nitrogen	0 to 8
15. Sulphocyanogen	Traces.

It will be seen that this table presents wide variations as to the percentage of the various gases. The illuminating power of the gas varies with the proportion of ethane, C_2H_6, ethylene (ethene), C_2H_4, acetylene, C_2H_2, and benzene, C_6H_6, and their homologues, and the heating value with the hydrogen, marsh gas, and carbon monoxide present. The specific gravity of coal gas is from 0.400 to 0.650, air being taken as 1.000.

The illuminating power of gas is measured by comparison with a standard spermaceti candle of six to the pound, and consuming, as near as may be, one hundred and twenty grains of spermaceti per hour. It is assumed that the light given off is in direct proportion to the sperm consumed. The gas to be tested is to be burned at the rate of five feet per hour. Such a burner should give as much light as sixteen or eighteen standard candles. It may reach as high as twenty-five or thirty candle-power.

Water gas may be referred to here as a gas manufactured and sold for the same purposes as coal gas. Its manufacture is conducted on a large scale in most cities, and to a large extent it has taken the place of coal gas.

This gas is manufactured as follows: Steam from a boiler is forced through a bed of glowing anthracite coals, previously heated to a very high temperature by an air blast. The steam from the boiler is passed through pipes or flues, over the fire box so as to superheat it to a temperature of 800° to 900° F. In passing this hot steam through the coals the water is decomposed, the oxygen combines with the carbon of the coal to form carbon dioxide, which is reduced, by the heated coal above, to the monoxide: (1) $C+2H_2O=CO_2+2H_2$. (2) $CO_2+C=2CO$. The hydrogen of the steam remains in a free state. After the steam has passed through the coal for about six minutes, the latter cools off and the process stops. The air blast is now turned on until the coal is again heated to the required degree—*i.e.* for about eight minutes—when the steam is again passed into it. It is, therefore, an alternating process. The gas thus produced has very little illuminating power, but answers well for heating purposes. To give illuminating power it must be charged with hydrocarbons. This is accomplished as follows: The decomposition products from the above process are conducted through an upright cylinder containing heated fire brick, into which a small stream of oil is running. The mixture of oil vapor and decomposition products is passed through another heated cylinder to render the vapor permanent gases instead of condensible vapors. By this Lowe process the carbureted gas is made in one operation instead of in two, as above described. Water gas is cheaper and usually of higher illuminating power than coal gas, and is consequently superseding the latter. In many cities in this country coal gas and water gas are made by two plants and mixed in the same gas-holder.

The principal differences in the chemical composition of coal gas and water gas are, that the latter, as

usually manufactured, contains a larger percentage of illuminating agents and of carbon monoxide than the former.

The following analyses of the two gases, by Professor Remsen and Dr. Love, will serve to illustrate these differences:

Constituents.	Remsen.		Love.
	Coal gas.	Water gas.	Water gas.
Carbon dioxide...	0.0	0.3	0.0
Illuminants (ethylene, propylene, butylene, ethane, propane, butane).....	4.3	12.85	15.75
Carbon monoxide.....	7.9	28.25	21.51
Hydrogen.....	50.2	30.30	46.49
Marsh gas (methane)	29.8	21.45	11.75
Nitrogen	7.8	6.85	4.30
Oxygen			0.20

Oil gas is now largely made by heating petroleum, tar, or shale oils in a retort to a temperature of about 1,000° C. This gas, especially that made by the Pintsch process, is much used in lighting cars. Oil gas is frequeutly used to enrich other gases of low illuminating power.

Air gas, so-called, is produced by passing air through layers of very light petroleum distillates, known as gasolene, when it takes up enough of the light hydrocarbons to form a combustible mixture. Air gas is much used where other gas is not available. It cannot be stored long or piped a long distance because of the condensation of the illuminants.

Acetylene, C_2H_2, is used as an illuminant in small lamps. It is prepared by treating calcium carbide with water, when the following reaction takes place:

$$CaC_2 + 2H_2O = Ca(OH)_2 + C_2H_2.$$

The calcium carbide is prepared by heating a mixture of powdered coke and lime in an electrical furnace. One ton of calcium carbide of eighty per cent. purity is said to produce 1,000 cubic feet of acetylene gas. Its illuminating power is very high, and when burned in an ordinary burner it gives off considerable soot. When burned in a specially constructed burner it gives a light of great brilliancy. Acetylene combines with copper and silver, forming acetylides, which are explosive. It combines with the hemoglobin of the blood, and thus acts as a poison. The gas has a pungent, suffocating, disagreeable odor, by which its presence in the air can usually be detected.

Fuel Gas and Furnace Gases.—Gases of more or less poisonous character are produced during various smelting and roasting processes and which may be the cause of serious accidental poisoning. The most commonly met with are arsine (arseniureted hydrogen), stibine (antimoniureted hydrogen), and sulphurous oxide, obtained by roasting ores containing arsenic, antimony, or sulphur, and CO_2 and CO obtained in smelting processes generally.

Carbon monoxide is an important constituent of *fuel gas* or *producer gas*. Producer gas is made by forcing air through a bed of incandescent coal or coke in specially constructed furnaces. It contains from twenty-five to thirty per cent. of CO, to which it owes its value as a fuel. It also contains some CO_2 and free nitrogen. In another form of furnace steam is forced through the heated coal, when CO and hydrogen are produced, as in making *water gas*. It is needless to say that both these gases are poisonous.

Natural gas is so called because it exists already formed in the earth whence it issues spontaneously, or is obtained by boring wells. The gas is found chiefly in localities where petroleum is found. It was used as an illuminating gas as early as 1821 in Fredonia, N. Y.

The "Burning Springs" of Baku, on the Caspian Sea, have been known since the sixth century B. C. The composition of natural gas is fairly uniform, and consists of about ninety per cent. of marsh gas (methane) with small quantities of ethane, C_2H_6, propane, C_3H_8, and other paraffin hydrocarbons, hydrogen, carbon monoxide, and carbon dioxide.

It is a valuable fuel, burning with a feebly luminous flame, but giving out an intense heat. In many localities it is the chief fuel. When heated in a suitable furnace with petroleum or the higher hydrocarbons, its illuminating power may be greatly increased and it is then used for illuminating purposes.

Poisonous Action of Illuminating Gases.—All forms of illuminating gas are irrespirable and more or less poisonous. They are irrespirable because they do not furnish oxygen. The chief poisonous agents are carbon monoxide and the heavier hydrocarbons mentioned above under the name of *illuminants*.

The physiological action of carbon monoxide has already been discussed in the article, *Carbon, Oxides of.*

The heavy hydrocarbons are more or less poisonous when mixed with air. The symptoms produced are dizziness, headache, nausea, and prostration. These compounds are more deleterious than is the lighter marsh gas, but their exact physiological action is not well understood. The physiological effects of illuminating gas are due not alone to the carbon monoxide, as some have supposed, but to the combined effect of this gas and the heavier hydrocarbons, together with the loss of oxygen due to the displacement of air by the gas.

Symptoms.—The symptoms of acute poisoning by ordinary illuminating gas are: headache, dizziness, nausea, a staggering gait, great muscular weakness, prostration, loss of memory, and finally, unconsciousness and complete asphyxia. Convulsions frequently end the scene. There is usually little difficulty in making the diagnosis, as the circumstances under which the patient is found, the odor of the gas, etc., will prevent deception. The only diseases likely to be confounded with this form of poisoning are cerebral apoplexy and uremic coma. Should the physician not see the patient before the odor of the gas has escaped, such difficulty might arise. In both of these diseases the symptoms are pretty constant, while in *coal-gas* or *water-gas poisoning* they are apt to fluctuate; the patient will frequently rouse up for a time, and answer questions intelligently, and then lapse into unconsciousness, or be seized with convulsions.

A marked difference in the symptoms will be noted, dependent upon whether the gas is admitted into the air rapidly or slowly. In the first condition the person rapidly becomes unconscious, and recovers rapidly when removed into fresh air. When the gas is admitted to the air of a room slowly, the headache, dizziness, nausea, and muscular weakness are the prominent symptoms, and they are remarkably persistent. The condition of the patient often seems to remain constant for days after the accident; and when entire unconsciousness has occurred, recovery is very unusual. We should distinguish between asphyxia by illuminating gas and poisoning by carbon monoxide obtained by breathing the diluted gas. The first is produced by a rapid displacement of the air of the room with the gas, while the second results from a slower and very gradual admixture of gas with the air.

Fresh air and stimulation will usually suffice to restore the patient in the first case; but in the second, while these measures should not be neglected, they are much less useful, and, when the time of exposure has been considerable, of slight benefit.

It may be well to name here some of the sources of coal-gas poisoning other than leakages directly from fixtures in the room.

The odor of the gas is so characteristic that this will in most cases give its warning. Repeated instances, however, prove that people may be killed by this gas without detecting the odor.

Cases of poisoning have occurred when the leak in the pipes occurred in an adjoining room, or in a cellar or other room underneath. Most of such accidents occur in the night while the victims are asleep, even though they were exposed to the same influences during the preceding day.

It should be known that these poisonous gases may diffuse themselves through walls, soil, and partitions. It should also be remembered that the odorous vapors may be almost entirely removed by diffusion through a thick wall or several feet of soil. The gas deprived of its odor may thus pervade the air of a sleeping- or sitting-room, and give no warning of its presence.

In winter, when the ground is frozen, and the upper layers are impervious to the gas, this may diffuse itself several feet laterally from a broken street main, reach the cellar, pass thence to the rooms above, and so do its deadly work unperceived. That this accident has frequently occurred is shown by abundant evidence taken from the statistics of any large city. Aside from the fatal cases of poisoning from this source, we can easily see that there must be a much larger number of cases in which headache, dizziness, loss of appetite, general debility, anemia, etc., may be dependent upon a smaller amount of the same gas continually finding its way into the air of houses.

It is evident, from the above, that cases of poisoning may occur in houses where gas is not used, and where the pipes do not even enter the house.

There has been, at various times, not a little discussion as to the relative poisonous effects of coal gas and water gas. This question has been made the subject of a great number of investigations. The weight of experimental evidence, however, goes to show that *water gas* is decidedly more dangerous than *coal gas*.

With a given amount of gas, the danger line is reached sooner with water gas; and, indeed, in many rooms it is not easy to get a fatal mixture of *coal gas* and air with the escape from a single burner jet, owing to natural ventilation through walls, floors, windows, etc. That is, dogs, cats, rabbits, and pigeons will endure almost indefinitely an atmosphere containing one per cent. of coal gas, while the same animals die in from five to eight hours when exposed to an atmosphere containing one per cent. of water gas.

The *postmortem appearances, in cases of poisoning by illminating gas*, are similar to those found after poisoning with carbon monoxide. There is generally an odor of the gas about the body, especially on compressing the chest, so as to expel the residual gas from the lungs.

The countenance may be pallid, pink, or purple, varying in different cases. Frequently more or less froth will be found issuing from the mouth, due probably to the nausea which precedes death, and which is one of the marked symptoms. Occasionally, rose-colored patches will be found on the thighs or other parts of the body.

When the body is opened the blood will generally be found everywhere in a fluid condition, and uniformly of a light red color on both sides of the heart. It shows the spectroscopic bands of carbon-monoxide hemoglobin. (see Fig. 1192, Vol. II, p. 624). The lungs will usually have a brilliant red hue, while the bronchial tubes will be filled with a frothy mucus. The venous sinuses of the brain and the vertebral nervous system will be found engorged with blood.

The above appearances are not always found, however, for there is great variation in this form of poisoning, both as to the symptoms and as to the postmortem appearances. These variations are probably explained by the fact that in some instances the cause of death is a true asphyxia, while in others it is CO poisoning. In the former we may expect a livid hue of skin, dark, clotted blood, and engorgement of the venous sinuses; while in the latter we may expect the light, fluid blood, the rose-colored spots upon the skin, a lingering death, etc. More careful observation is needed upon these points.

Treatment.—We have incidentally mentioned nearly all that can be said of the treatment of coal-gas poisoning. If the case is one of suffocation, and the time of exposure has not been too long, fresh air or pure oxygen inhalations, stimulants, and rest will usually suffice to restore the patient to consciousness. When the exposure to the gas has exceeded five or six hours, recovery can scarcely be expected, because of the degree of saturation of the hemoglobin of the blood with CO, and its inability to combine with oxygen.

No antidote for poisoning by the gas is known. Transfusion of blood has been tried with apparent success.

In experiments upon the lower animals the introduction of normal salt solution into the veins has occasionally been successful in saving life.

Inhalations of oxygen have often been tried, with temporary benefit, but it does not seem to expel the carbon monoxide from the blood. If persisted in, and especially if combined with artifical respiration by means of the pulmotor, it may save life when the blood is not too nearly saturated with the gas.

ELIAS H. BARTLEY.

Gasser, Johann Lorenz.—An Austrian anatomist of the eighteenth century of whom little is known. To him is attributed the discovery of the semilunar ganglion, but the true discoverer was Hirsch, a pupil of Gasser's, who, in order to perpetuate the name of his master, called this ganglion the Gasserian ganglion.

E. L. J.

Gasserian Ganglion, Excision of the.—See *Brain, Surgery of the.*

Gastein (Wilbad-Gastein).—A mountain valley in the Austrian Alps at the upper end of which is situated Bad Gastein at an altitude of 3250–3430 feet above sea level. It is connected by rail with Salzburg from which it is sixty-six miles distant. The river Ache runs through the village, which forms two waterfalls, one of which is 270 feet in height, the roar of which is sometimes disturbing to nervous people at night. The situation in the midst of mountains and in the near region of glaciers is grand and picturesque.

The season extends from May to October, and the climate during this period is of an Alpine character, fresh and invigorating. Frequent and sudden changes of temperature, however, occur, and there are many cool and showery days, even in July and August, but the showers do not last long. It is claimed that the thermometer has never gone above 86° F. in summer and seldom above 70°.

The permanent number of inhabitants is about 800 and the annual number of visitors exceeds 11,000.

The springs, eighteen or twenty in number, are warm, of a temperature of 87° to 160°, and are of the class of indifferent thermal waters feebly mineralized, containing small amounts of sodium sulphate, calcium carbonate and sodium chloride. They are employed almost entirely for bathing, for which purpose the equipment is excellent, there being many public and private bath establishments.

The waters have been known and used since the seventh century, and this resort is now one of the most famous watering-places in Europe.

The baths are employed for nervous affections of various kinds, both functional and organic: Neuralgia, gout, rheumatism, chronic metritis and pelvic exudations, disorders of nutrition, anemia, and in senile debility. Their beneficial effects in this latter condition has given them the name of "old folks' baths."

Gastein is also recommended on account of its mountain climate as an after-cure to a course at Carlsbad, Marienbad, and other springs.

In 1898 radium was first discovered in these waters and they are said to surpass those of any other spa in quality of radioactivity, and it may be that it is owing to this radioactive element that the beneficial results obtained are due. The radioactivity is manifest in a gas-like substance called "emanation" which is regarded as exercising the chief therapeutic influence of this strange, powerful metal. It has been observed that radium "emanation" exercises no evident influence upon persons in health, but in certain pathological conditions a definite reaction follows an "emanation" bath.

The accommodations are excellent and abundant and there are warm baths in the hotels. There are reliable physicians, an English Church service, and the usual attractions found in bath resorts. There are many pleasant promenades and walks, and although the latter are mostly up-hill, there are plenty of benches to rest upon.

Life is quiet here, as the frequenters are mostly nervous and elderly people. It is a good place in which to renew one's strength or conserve what is left.

EDWARD O. OTIS.

Gastrectomy.—See *Stomach, Surgery of the.*

Gastric Juice.—Prior to the middle of the eighteenth century little was known concerning the nature and action of gastric juice. The theories advanced to explain the digestion of food in the stomach were numerous and varied. Thus Hippocrates likened this process to one of coction, the change in the food materials being induced by the influence of heat. Asclepiades considered the process similar to trituration, the stomach alternately contracting and relaxing, thus mechanically reducing the food under the influence of heat to a fluid condition in which form it was distributed to all parts of the body. To van Helmont belongs the credit of introducing the idea of fermentation as explanatory of digestive action. "Under the influence of the archæus—as he termed the vital principal which presided over the processes of the organism, shaping its elements into the various forms of matter which compose its tissues and organs—there is generated in the stomach a ferment, whereby an acid is produced which brings about the solution of the food."

In 1752 the French naturalist Réaumur demonstrated that meat is dissolved in the stomach of a tame buzzard. In order to obtain the substance effecting this solution Réaumur placed pieces of sponge in small metallic tubes. The buzzard, like other birds of prey, possesses the power of regurgitating indigestible materials, hence when the metallic tubes were ejected, the enclosed sponge contained an acid fluid with considerable antiseptic properties. Stevens (1777) came to essentially the same conclusions by experimenting on a human being who possessed the power of regurgitation, and he was the first to carry out digestion experiments outside the body by means of the gastric juice of the dog. The researches of Spallanzani (1777–83) showed conclusively that gastric juice was capable of effecting the same transformations when removed from the body, if the conditions for its activity were favorable, as in the stomach itself. Attention was called to the antiseptic nature of the fluid, and without knowing the cause of the acidity of the gastric juice he yet recognized it and asserted that the acid reaction ceases when digestion is completed. It was he who first gave the name gastric juice to the secretion of the stomach.

The early history of the knowledge concerning gastric juice closes with Spallanzani. After him came Tiedemann and Gmelin, and Leuret and Lassaigue who especially turned their attention to the acidity of gastric juice. Then followed the classic observations of Beaumont (1825–33), a surgeon in the United States Army, and his contributions may justly be called the most important ever made to the science of gastric digestion. His experiments were made upon a Canadian, Alexis St. Martin, in whom a permanent gastric fistula remained after a gunshot wound. The gastric juice was described as "a clear, transparent fluid, inodorous, a little saltish, and very perceptibly acid. Its taste when applied to the tongue is similar to thin mucilaginous water slightly acidulated with muriatic acid." He further described it as powerfully antiseptic, and an effectual solvent of food.

In the winter of 1832–33 Beaumont sent a sample of gastric juice contaminated with a little mucus for examination to Professor Dunglison of the University of Virginia. Dunglison in collaboration with Professor Emmett reported that he had found the gastric juice to contain "free muriatic and acetic acid, phosphates and muriates, with bases of potassa, soda, magnesia, and lime, and an animal matter soluble in cold water, but insoluble in hot."

Prout in 1824 had already declared that the acidity of the gastric juice was due to free hydrochloric acid, and Eberle in 1834 announced the interesting fact that by acting upon the stomach mucous membrane with dilute hydrochloric acid a fluid may be obtained whose action upon the food coincided with that of the natural gastric juice. Soon afterward (1836) Schwann concluded that the gastric juice owed its digestive power to some unknown active principle to which he gave the name pepsin. Schwann was unable to isolate the active substance as a distinct chemical entity. Wassmann, however, in 1839, prepared an impure pepsin as a yellowish powder soluble in water.

Lab ferment, or rennin, was discovered and isolated (also in impure form) by Hammarsten in 1872.

The observations of Beaumont on Alexis St. Martin led to the suggestion that gastric fistulas be made on animals, and in 1842 Bassow first performed this operation. Since then many such operations have been made on man and animals and recently Pawlow has greatly improved the surgery of gastric fistula and has added many valuable facts to the study of gastric juice, particularly concerning the secretion of this fluid. Although it was assumed by the older investigators that the secretion of gastric juice is under the control of the nervous system, the actual demonstration of this fact is the work of Pawlow and his pupils. They have especially investigated this point through the establishment of a gastric fistula in dogs already possessing an esophageal fistula. In this way it became possible to study the influence of nerve stimulation on the one hand and the direct action of food on the mucous membrane of the stomach on the other, and this arrangement also afforded an excellent opportunity for the collection of gastric juice free from food and saliva. Following a method suggested by Heidenhain they also formed in other dogs a blind sac or little stomach by partial dessection of the fundus portion of the stomach, and in this sac the secretory processes could be studied while digestion was going on in other parts of the stomach.

Gastric secretion is under the direct influence of the nervous system and the secretory fibers are contained in the vagus nerve, for a secretion of gastric juice may be induced by direct stimulation of the peripheral end of the cut vagus. As further proof of the influence of the vagus on gastric secretion Pawlow performed the following experiments: To a dog with an esophageal and gastric fistula food was given. The

animal thus had the pleasure of eating without food entering the stomach, for as soon as the bolus was swallowed, it was discharged to the exterior through the esophageal fistula. The investigator called such feeding sham feeding (Scheinfütterung). So long as the vagus was intact sham feeding caused an abundant secretion of gastric juice. As soon, however, as this nerve was severed gastric juice failed to be secreted under the above conditions. It is apparent therefore that the sensations of taste, odor, etc., induced during the processes of mastication and swallowing bring about a reflex stimulation of the vagus nerve. A secretion brought about in this way is called a psychical secretion by Pawlow and it is implied that the reflex is attended by conscious sensations. Such a secretion may continue for a long period after the stimulus has ceased. Under similar conditions Hornborg has shown that comparable results may be obtained. Thus in a boy with a stricture of the esophagus and a gastric fistula food chewed and swallowed was regurgitated, and although none of it reached the stomach, an active psychical secretion of gastric juice fowlloed.

The modern idea concerning the secretion of gastric juice is as follows: The mechanical factor of food as a factor in gastric secretion may be eliminated since Pawlow has definitely demonstrated that it is without influence in this direction. Under ordinary circumstances gastric secretion is first started by the sensations of eating, that is, by psychical stimulation and is a reflex. The psychical stimulation therefore starts gastric digestion which is continued by an action occurring in the stomach itself. It has been demonstrated that certain foods contain substances which act specifically in calling forth a secretion of gastric juice when taken into the stomach. Other foods do not possess these bodies, these secretagogues as they are designated. Bread and egg white contain little or no secretagogues, milk causes some secretion, but meat extracts, meat juices, and soups are particularly rich in secretagogues. Again, those foods which may not contain ready formed secretagogues may form them since it has been shown quite clearly that the products of gastric digestion induce a copious secretion of gastric juice. The way in which secretagogues induce a flow of gastric juice is not definitely settled but Edkins has suggested that secretagogues, whether preformed in the food or formed during digestion, act upon the pyloric mucous membrane in such a manner that a new substance is formed, namely, *gastrin* or *gastric secretin*. This substance is absorbed into the blood, is carried to the gastric glands and stimulates them to action. This type of action is comparable to the way in which pancreatic secretion is induced and one may therefore assume the intervention of a nervous stimulation and a chemical stimulation in the secretion of gastric juice. *Gastrin* or *gastric secretin* belongs to the group designated by Starling as *chemical messengers* or *hormones* (which see).

The work of Pawlow has also indicated that the quantity and character of the gastric juice is closely related to the kind of food eaten. In the first place the quantity of juice secreted is proportional to the amount of food ingested. The juice obtained with various kinds of food varies in acidity and digestive power, thus the acidity is greatest with a meat diet and lowest with bread; the quantity of enzyme is, on the contrary, highest with a bread diet and lowest with a milk diet. It has also been demonstrated by the same investigator that gastric secretion may be influenced by the small intestine, and in this way the fats have a retarding action upon the secretion of juice and upon digestion by acting reflexly upon the duodenal mucosa. If fat is fed with food containing starch the secretion of gastric juice remains reduced during the entire period of feeding. Fat in connection with protein food has a similar influence, with the exception, that under these circumstances the retarding action is observed only during the first hours of digestion.

Human gastric juice, which can seldom be obtained pure and free from residues of food or from mucus and saliva, is a clear, or only very faintly cloudy, and nearly colorless fluid of an insipid acid taste and strong acid reaction. It contains as form elements glandular cells or their nuclei, mucous corpuscles, and more or less changed columnar epithelium.

The acidity of gastric juice is due to the presence of free hydrochloric acid. Although there are numerous theories to account for the formation of hydrochloric acid in the stomach none is satisfactory. After partaking of food rich in carbohydrates, lactic and sometimes acetic and butyric acids may be present. The quantity of hydrochloric acid varies greatly according to the period of digestion, but since it has been possible to obtain pure human gastric juice the researches of Umber, Hornborg, Bickel, and Sommerfeld have shown that the amount is about four to five per mille. There is little doubt that a portion of the hydrochloric acid exists combined with organic substances, especially proteins, and hence does not exist free in the ordinary sense.

The specific gravity of gastric juice varies from 1.001 to 1.010 and is correspondingly low in solids. Albu found in the ash of pure human gastric juice 356.2 per mille K_2O; 226.5 per mille Na_2O, and 497.3 per mille Cl. The amount of salts insoluble in water was 23.9 per mille.

Besides the free hydrochloric acid, pepsin, rennin, and a lipase are the other recognized physiologically important constituents of gastric juice.

Pepsin is a typical proteolytic enzyme possessing the peculiarity of acting only in an acid medium, and hence protein digestion in the stomach is the result of the combined action of pepsin and hydrochloric acid. Pepsin is present in new-born infants although this is not true for the young of some animals. In man the enzyme is supposed to be formed in the chief cells of the gastric tubules and is present in the cells as a precursor or zymogen—pepsinogen which is readily transformed into active pepsin by hydrochloric acid. Like all enzymes pepsin is sensitive to changes in temperature—low temperatures retard and may even suspend activity without, however, necessarily destroying the enzyme—high temperatures tend to accelerate pepsin action—the optimum temperature being from 37° C. to 40° C. Heating to 80° C. for some time will result in the total destruction of pepsin if it is in a moist condition. Pepsin has never been isolated in a pure condition. It is probable that pepsin is not a protein. It is soluble in water and glycerin and may be precipitated from its solutions by alcohol and is slowly destroyed thereby. Pepsin is exceedingly sensitive to the influence of alkalies, being made inactive by these substances. The only known property of pepsin is that it dissolves proteins in an acid medium with the production of proteoses and peptones.

So far as our knowledge goes the action of rennin is confined to milk—causing a coagulation in neutral solutions. Rennin is just as difficult to obtain pure as other enzymes and in general presents characteristics typical of enzymes as behavior toward changes of temperature, etc. Pure rennin solutions fail to yield protein reactions. There is some evidence that rennin-like enzymes from different sources are not identical. Thus the active principle obtained from the calf's stomach, called rennin or chymosin, is unlike that found in the stomach of the pig and man. The latter enzyme has been named parachymosin. For general purposes the term rennin is used indiscriminately. A question which has been subjected to much controversy is whether the pepsin and rennin action are induced by two distinct enzymes, or represent two enzyme actions, or whether there is

only one enzyme, the pepsin, which possesses both activities. The fact that enzymes having a proteolytic and rennin action occur simultaneously in both the plant and animal kingdoms indicates either an identity of enzymes or at least a parallelism of their actions. Although the views put forth relative to this question are many and varied, perhaps the most generally accepted theory is that of Nencki and Sieber who regard pepsin as a great molecule with many side chains one of which digests protein in acid solution, the other causes milk to coagulate in neutral solutions. This view agrees fairly well with most of the observations thus far made.

In 1900 Volhard observed that gastric juice has a strong fat-splitting action when the fat is in fine emulsion as in the yolk of egg, in milk or in cream. Although a great deal of controversy has been aroused by this discovery its importance is still problematical and even though its existence has been denied there is little question that a gastric lipase occurs and is secreted with the gastric juice.

FRANK P. UNDERHILL.

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Gastritis.—See *Stomach, Diseases of the.*

Gastrodiscus.—A genus of flukes in which the body is slender, broadened posteriorly into a large concave disc at the posterior border of which the small ventral sucker lies. *G.* (*Amphistomum*) *hominis* has sometimes been found in great numbers in natives in India. This species is believed to occur normally in the horse. See *Trematoda.*

Gastrula.—(Dim. of L. *gaster* from the Greek γαστήρ, belly, stomach.) The *gastrula* is a stage in the embryonic development of a least one representative of nearly every great group of animals

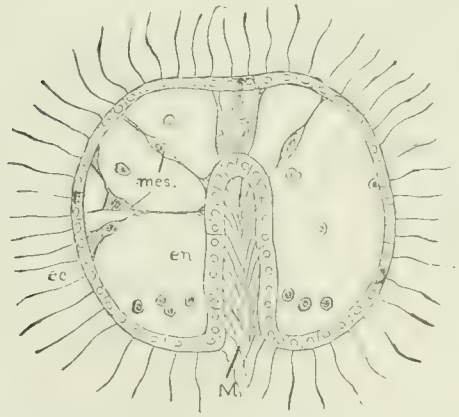

FIG. 2686.—Section of a Gastrula of a Sea-Urchin, *Toxopneustes lividus*. (After Selenka.) Highly magnified. *ec*, Ectoderm; *en*, Endoderm; *mes*, mesenchyme; *M*, blastopore.

above the Protozoa. Moreover, those forms which do not possess a typical gastrula stage are found on careful examination to exhibit, with few exceptions, structures or modes of development which may be interpreted as vestiges of this stage.

In holoblastic eggs with equal cleavage (see article *Segmentation of the Ovum*) the cleavage results in the formation of a typical *blastula*. This is a rounded body composed of cells, the *blastomeres*, forming a continuous membrane, which encloses a cavity, the *blastocœl*. This first embryonic stage is said to be *monodermic*, because it consists essentially of a single layer of similar cells. In its simplest form this layer is one cell thick, but it may be many cells in thickness.

The next stage is the *gastrula*, which is formed from the blastula usually by the invagination of its wall on one side. By this process the blastoderm becomes differentiated into the two primary germ layers. The gastrula stage is therefore essentially *didermic*. The

FIG. 2687.—Sagittal Section of a Gastrula of Amphioxus at 4 A. M. *a*, Anterior pole; *d*, dorsal lip of the blastopore; *v*, ventral lip. Reduced from camera drawing made with Zeiss 4, oil immersion 2 mm. (After Morgan and Hazen.)

part which remains on the outside is the *ectoderm*, and the part which is invaginated is the *endoderm*. (See *Germ Layers.*) In most animals the cells of the blastula are not all alike, those on one side, the animal pole, being smaller and containing less deutoplasm (yolk granules) than those on the other side, the vegetal pole, which are in many cases very large and heavily laden with deutoplasm. When such differentiation obtains it is always the cells of the vegetal pole that are invaginated to form the endoderm.

The nearly typical gastrula of a sea-urchin is represented in longitudinal section in Fig. 2686. This embryo contains two cavities—one a closed cavity, the blastocœl, lying between the ectoderm (*ec*) and the endoderm (*en*), and the other, the primitive stomach, or *archenteron*, a cavity entirely surrounded by endoderm, except at one side, where it opens to the exterior by the primitive mouth, or *blastopore* (*M*). At the lips of the blastopore the ectoderm and endoderm are continuous. This embryo is not quite a typical gastrula on account of the presence in the blastocœl of mesenchyme cells (*mes*), which in most animals appear at a somewhat later stage.

Gastrulas of this same general type are to be met with in the sponges, celenterates, echinoderms, nemertians, annelids (Eupomatus), sipunculids, chetognaths, crustacea (Lucifer), mollusks, and chordata (tunicates and Amphioxus).

Of these various forms, the one of most interest to us is the gastrula of Amphioxus. If one were to draw a diagram to show the essential structures of a verte-

brate reduced to their simplest forms, the drawing with slight alterations could be made to represent an amphioxus. This is a little fish-like animal an inch or two in length, that lives in the sand in shallow arms of the sea in various parts of the world. It is found in the Chesapeake Bay, in the lagoons of the Bahamas, and the writer has gathered hundreds of specimens on the sand flats by the railroad wharf at Port Tampa, Florida. The Amphioxus, having little more than a notochord by way of skeleton, has left no fossil remains, but its habitat is exactly similar to that in which countless generations of Lingula have dwelt with practically no change of structure, so far as we can see, since lower Silurian times. So it is not impossible that we may be right if we infer from its structure that Amphioxus is also of a very ancient type, and is a living representative of our ancestors, that lived before the appearance of the earliest fishes. For this reason the embryology of this form is of special interest. This proves to be just as diagrammatically primitive as the adult structure and confirms our inference from comparative anatomy.

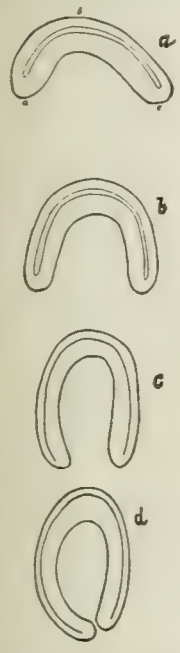

FIG. 2688. — Four Stages in the Development of the Gastrula and Closure of Blastopore of Amphioxus. Sagittal sections. *a*, Ventral lip of blastopore; *b*, anterior pole; *c*, dorsal lip. (After Morgan and Hazen.)

The gastrula of Amphioxus (Fig. 2687) is a typical one of the *embolic* type. That is, the archenteron is formed, as in the sea-urchin, by the invagination of the endoderm. This is contrasted with the *epibolic* type of gastrula in which, owing to the large size of the slowly dividing endodermal cells, heavily laden with yolk, an invagination is impossible,

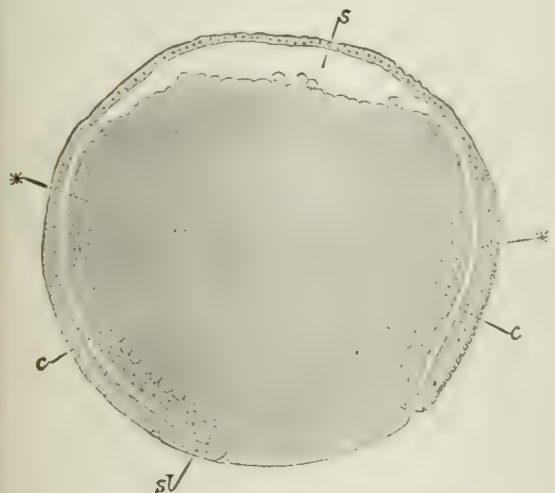

FIG. 2689.—Sagittal Section of a Gastrula of Forty Hours of the Garpike, Lepidosteus. *c*, Endoderm; *sl*, dorsal lip of blastopore; *s*, blastocœl; **, innermost limit of archenteron. (After Dean.) × 30.

and the smaller and more active ectodermal cells form the gastrula by growing over and around the large and less active endodermal cells. These types of gastrula grade into one another, so that in some cases it is difficult to tell to which type the gastrula belongs.

Fig. 2687 represents a vertical longitudinal section of a gastrula of Amphioxus. The archenteron is large and the endoderm is so closely pressed against the ectoderm that the blastocœl is obliterated except in a small space near each lip of the blastopore, which at this stage is widely open. The development of the gastrula of this species is represented in Fig. 2688.

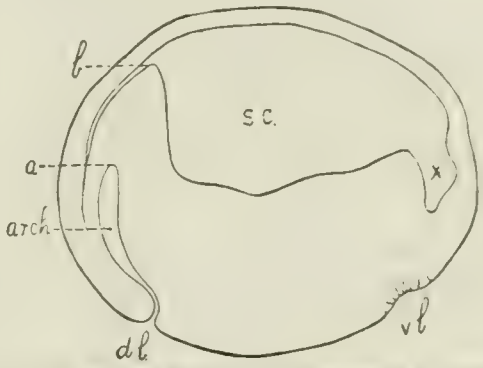

FIG. 2690.—Sagittal Section of the Gastrula of a Tree-toad, Chorophilus. *arch*, Archenreton; *a–b*, "tongue" of uncleft yolk in front of archenteron; *d.l.*, dorsal lip; *v.l.*, ventral lip, *s.c.*, blastocel; *x*, space produced artificially. (After H. V. Wilson.) Camera drawing, Zeiss A, 2.

The eggs of Amphioxus are laid, according to Wilson, as a rule, between five and six in the afternoon. Cleavage results in the formation of a globular blastula; and about midnight, according to Morgan, gastrulation begins by the flattening of one side of the blastula. This side may be distinguished from the other by the presence of larger cells more completely filled with yolk granules. About two hours later the flattened side has pushed inward until the endoderm nearly touches the ectoderm and the embryo has become saucer-shaped (Fig. 2688, *a*). From this time on there is a gradual closing of the blastopore accompanied by the growth of its lips, until, when the blastopore is nearly closed, the embryo has the shape of a

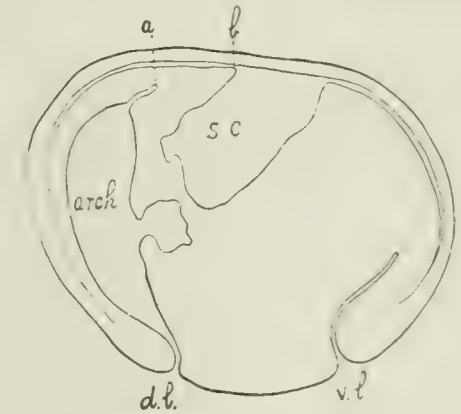

FIG. 2691.—Sagittal Section of the Gastrula of a Tree-toad-Chorophilus. Later stage than that shown in Fig. 2690. Reference letters the same. (After H. V. Wilson.) Zeiss A, 2.

football (Fig. 2688, *d*), the small opening being a slight distance from the posterior end of the long axis of the embryo and on the dorsal side of it. The end of the gastrula stage is marked by the closure of the blastopore from direct communication with the exterior. But for a long time the inner part of it forms a passage-

way from the archenteron into the developing neural tube, it is then called the *neurenteric* canal.

The simplest form of gastrula to be found in the true vertebrates is of the type observed in the cyclostomes, ganoids (Fig. 2689), and amphibians (Figs. 2690 and 2691). In the eggs of these forms the cleavage is always unequal and may be holoblastic as in the frog or meroblastic as in the gar-pike. In either case it results in the formation of a blastula in which the blastocœl is excentric, lying near the upper pole. In either case the roof of the blastocœl is composed of one or more layers of small cells, while its floor is composed of large cells or imperfectly divided yolk. The development of the gastrula begins by the appearance of a slight groove on one side below the edge of the area of small cells. The formation of the groove seems to be due to an *invagination* of cells of the vegetal pole. The upper edge of this groove is the dorsal lip of the blastopore. The ends of the groove

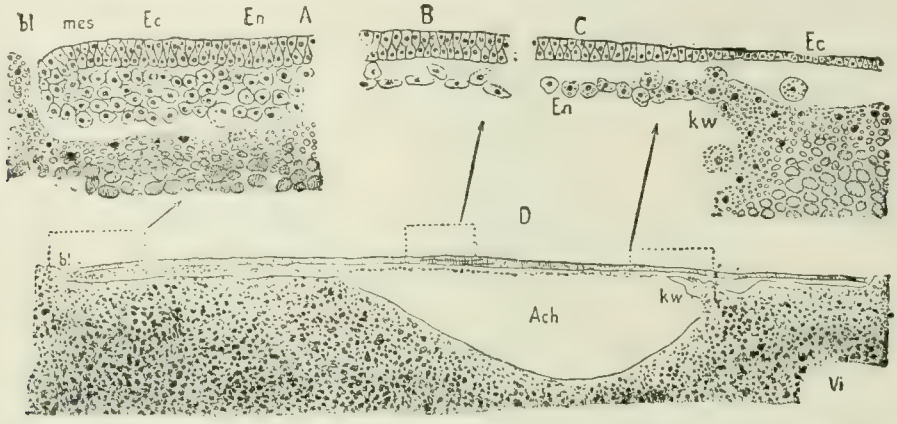

Fig. 2692.—Sagittal Section through the Blastoderm of a Hen's Egg Incubated Six Hours. *Ach*, Archenteron; *bl*, dorsal lip of blastopore; *Ec*, ectoderm; *En*, endoderm; *kw*, germinal wall; *mes*, marginal rim; *Vi*, Yolk. (After Duval, from Minot.) *D*, × about 40; *A*, *B*, *C*, details of *D* more highly magnified.

extend in a circle until they meet, completing the blastopore at its ventral lip. Within the blastopore there is a mass of large endodermal cells, the so-called *yolk-plug*. The formation of the blastopore has been observed in living eggs of a number of amphibians by several investigators. The observations of H. V. Wilson upon a tree frog (*Chorophilus feriarum*) are of special interest because by the skilful use of an inverted microscope he was able to watch the changes in uninjured eggs in their normal position. He finds that all parts of the edge of the blastopore, as soon as they are formed, begin to grow over the yolk cells. During this process, not only the yolk cells disappear under the advancing edge of the blastopore, but cells outside of the blastopore are seen to move to the edge and then to roll over and disappear beneath it so that there is here a combination of overgrowth (*epiboly*) and in rolling (*involution*). The dorsal lip being the first to form, Wilson finds that it grows over an angular distance of 25° before the ventral lip starts, at which time the width of the blastopore is 95°. After that the rate of closure is equal on all sides.

When the blastopore has been reduced to a very small opening, the overgrowth stops at the dorsal and ventral sides, but continues laterally, so that the blastopore finally becomes a mere slit and at length the lips fuse in the middle, leaving a minute opening at each end. The dorsal one is the neurenteric canal, and the ventral one may or may not persist as the permanent anus.

Figs. 2689, 2690, and 2691 represent sagittal sections of gastrulas of the gar-pike and the tree frog. Comparing these with Fig. 2687 we see that they are similar to the gastrula of Amphioxus, except that in these forms the endoderm forming the ventral and anterior wall of the archenteron is greatly thickened so as nearly to fill the cavity of the archenteron and to protrude through the blastopore.

In the Sauropsida, reptiles and birds, we find an enormous increase in the proportion of yolk in the egg. Nevertheless, there is a stage in the development of these forms that may be regarded as a gastrula. The best account of avian gastrulation is Patterson's (1907) description of the gastrulation of the pigeon. Cleavage begins and the egg passes through the blastula stage while in the oviduct. The germinal area at the close of segmentation is three to four cells deep, except at the edges. The first step toward the gastrula stage, is a thinning out of the germinal disc, accompanied by an increase in area and the deepening of the subgerminal cavity lying between it and the yolk. The thinning takes place chiefly in the posterior quadrant of the germinal disc, and gastrulation seems to begin by an inrolling of the thin free edge of the posterior margin of the blastoderm. In this region of invagination or involution there is a rapid thickening of the margin which results in a condition similar to that described by Duval in the chick.

Fig. 2692 represents a sagittal section through a late gastrula stage of the hen's egg and may be compared with the dorsal half of the gastrula of the frog, Fig. 2691. At the anterior end of the section the ectoderm is seen to be growing over the yolk while the endoderm below is continuous with the yolk (*kw*), while at the posterior end the endoderm and ectoderm are continuous with one another and separated from the yolk by a slit (*bl*), which connects with the archenteron and may be regarded as homologous with the blastopore of the frog.

In the mammalia, although the egg is minute and undergoes a holoblastic cleavage, the development of the embryo is a very complex process, to be explained probably by the supposition that the ancestors of the mammals had eggs with a large amount of yolk. In this group the gastrula stage has almost entirely disappeared, the stage figured by Haeckel as such not being a gastrula at all. Hubrecht, however, described structures in the primitive streak of the shrew (Sorex) that resemble what is found at the lip of the blastopore of the frog, and he finds there a minute canal that he regards as a vestige of the neurenteric canal.

So far we have treated gastrulation as chiefly a process of invagination that results in the conversion of a monodermic into a didermic embryo. This

correctly describes the process that results in the typical gastrula of invertebrates. But, as first pointed out by Hubrecht, gastrulation in the vertebrates is a more complex process. It is divided into two phases. These are most evident in the development of the Sauropsida, but they may be distinguished in all other vertebrates, including Amphioxus. The first phase, or gastrulation proper, results in the didermic condition, in which ectoderm and endoderm are distinctly differentiated. Above Amphioxus, delamination, or splitting, replaces invagination more and more as the method of formation of the endoderm, until in many vertebrates no invagination can be observed. The second phase, called *notogenesis* by Hubrecht (1908), results in the formation of groups of cells from which are to arise the notochord and the mesoderm. It is associated with the closure of the blastopore and the formation of the primitive streak (see articles *Area embryonalis* and *Blastopore*.)

The gastrula has been a stage of more than ordinary interest to embryologists because of the importance attributed to it in the *Gastræa Theory* of Haeckel. This theory is based primarily upon the discovery made by Huxley in 1849: "That a Medusa consists essentially of two membranes enclosing a variously shaped cavity, inasmuch as its various organs are so composed"; and that "a complete identity of structure connects the foundation membranes of the Medusa with corresponding organs in the rest of the series; and it is curious to remark, that throughout the outer and inner membranes appear to bear the same physiological relation to one another as do the serous and mucous layers of the germ; the outer becoming developed into the muscular system and giving rise to the organs of offence and defence; the inner, on the other hand, appearing to be more closely subservient to the purposes of nutrition and generation." To these two layers Allman in 1853 gave the names ectoderm and endoderm, respectively. Later, Alexander Kowalevsky, beginning in 1866, made a brilliant series of observations upon the embryonic development of a large number of invertebrates, corals, hydromedusæ, scyphomedusæ, ctenophores, worms, Phoronis, brachiopods, echinoderms, mollusks, and insects, and also upon various lower chordata, including tunicates, Amphioxus, and fishes. He concluded that in all the invertebrates that he had studied, two germ layers are formed at the beginning of development, and that in most cases there is formed at first a vesicle of cells, one side of which becomes invaginated, forming a double cup with a central cavity opening to the exterior. He found a similar condition in tunicates and Amphioxus and by comparison of their subsequent stages of development demonstrated the affinity of the tunicates with Amphioxus and, through that form, with the true vertebrates.

In 1872 Haeckel published a description of the two-layered, cup-shaped larva of the calcareous sponges, and asserted that this stage, to which he gave the name *Gastrula*, is a fundamental one for all metazoa.

In 1874 and 1875 he elaborated more fully the theory that the gastrula represents the type of the most primitive metazoan, the common ancestor of the whole great group of animals above the protozoa. To this hypothetical ancestor he gave the name *Gastræa*. As already indicated, this generalization of Haeckel has been, in the main, confirmed by subsequent investigations.

ROBERT PAYNE BIGELOW.

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Gaultheria.—WINTERGREEN, *Partridge Berry, Tea Berry, Box Berry.*

The dried leaves of *Gaultheria procumbens* L. (fam. *Ericaceæ*). This plant is a little evergreen undershrub, with slender, weak, creeping or subterranean stems, which are at intervals ascending or erect; branches from two to four inches high, each bearing three or four leaves and a few axillary, nodding flowers; leaves oval or obovate, thick, leathery, almost entire,

FIG. 2693.—Wintergreen; Leaves and Berries. (Baillon.)

bright-green and shining above, paler beneath, with slightly revolute margins, fragant when crushed, and pleasantly aromatic to the taste. Flowers small, calyx five-toothed, enclosing the small capsule, becoming fleshy as it ripens, and forming the principal portion of the fruit. Corolla ovoid, five-toothed; stamens, ten; pistil, one, with five-celled ovary; pod, five-celled, many-seeded, surrounded by the juicy calyx. The berry, which is edible and occasionally found in the markets, is about a fourth of an inch in diameter, pink or red in color, of a sweetish, aromatic, birch-like taste.

Gaultheria is a native of North America, growing in dry woods and plains. It is in many parts of the United States very abundant, carpeting the ground under trees and bushes, and is collected in large quantities both for use, dried, and for immediate distillation. All parts are aromatic, the leaves and stems astringent as well, and owe their value to an essential oil (*Oleum Gaultheriæ*, U. S. P.) of birch-like flavor, consisting mostly of *methyl salicylate*, with about one-tenth of a peculiar hydrocarbon, *gaultherilene*. Oil of wintergreen is a colorless, yellow or reddish liquid (according to age), of a peculiar strong and aromatic odor, a sweetish, warm, and aromatic taste, and a slightly acid reaction. Specific gravity 1.172 to 1.180 at 25° C. (77° F.) Its boiling point is 218° to 221° C. (424.4° to 429.8° C.). It is slightly levogyrate, up to −1° in a 100-min. tube, at 25° C. (77° F.). In other respects it is identical with artificial methyl salicylate.

Like sassafras, cinnamon, and other pleasant aromatics, wintergreen is very largely used as a flavor, and enters into several official preparations for that purpose. Its relation to salicylic acid has led to its employment in rheumatism. The discussion is very animated as to whether oil of wintergreen, oil of birch, and pure methyl salicylate are identical in physiological action. By many the natural oil of wintergreen is preferred to either of the others. Dose of the leaves, gr. xv.–lx. (1.0–4.0); of the oil, gtt. v.–xx. (0.3–1.2).

Preparations: Of the oil, spirit (*Spiritus Gaultheriæ*, U. S. P.) 0.05 in alcohol. HENRY H. RUSBY.

Gaylord and Gulick Mineral Springs.—(Formerly Blossburg Mineral Springs.) Tioga County, Pennsylvania.

POST-OFFICE.—Blossburg. Hotels in the village.

ACCESS.—Viâ Tioga branch of Erie Railroad to Blossburg; also viâ Northern Central Railroad to Roaring Branch, and thence by conveyance over the mountains.

These springs are located in a picturesque mountain region 1,500 feet above the sea-level and are within half a mile of the railroad. They are surrounded by a charming tract of woodland containing 213 acres, from which a fine view of the valley of the Tioga may be obtained. The place offers many attractions as a summer resort. The springs are two in number, and flow about 1,800 gallons of water per hour. The following analysis was made by Prof. F. A. Genth in 1879.

SULPHATED ACID CHALYBEATE.

ONE UNITED STATES GALLON CONTAINS:

Solids.	Grains.
Magnesium sulphate	13.10
Calcium sulphate	23.13
Lithium sulphate	0.12
Sodium sulphate	0.27
Potassium sulphate	0.24
Sodium chloride	0.10
Manganese sulphate	1.83
Cobalt sulphate	0.03
Nickel sulphate	0.36
Aluminum sulphate	6.58
Iron sulphate	31.31
Iron phosphate	0.32
Sulphuric acid	5.64
Silicic acid	2.15
Total	85.18

This analysis shows a sulphated acid chalybeate water of great potency. It is remarkably rich in ferruginous ingredients, and contains a considerable proportion of the sulphate of magnesia or Epsom salt. The analysis also shows appreciable quantities of the rare ingredients manganese, nickel, and cobalt. The water possesses excellent properties as a tonic and reconstructive, and has been found very useful in conditions characterized by anemia and general debility. It is also used in dyspepsia and intestinal disorders. Locally it has decided astringent and stimulant effects, and as such is recommended as a douche, spray, gargle, or lotion. The water is used commercially. A mineral water of this strength should always be taken under the direction of a physician.

EMMA E. WALKER.

Gegenbaur, Karl.—Born in Würzburg, Germany, August 21, 1826. During the years 1845–1850 he studied chiefly under Virchow and Koelliker. From 1850 to 1852 he was an assistant in the Julius Hospital; and during the following year (1852–1853) he devoted his time to the study of the lower orders of marine animals of the Mediterranean on the coast of Sicily. During the next twenty years he taught anatomy and physiology, first in Würzburg and next in Jena. In 1873 he was called to Heidelberg as Professor of Anatomy and Director of the Anatomical Institute, both of which positions he held up to the time of his death in 1903.

Of his published writings the following deserve to receive special mention: "Untersuchungen über Pteropoden und Heteropoden," Leipzig, 1855; "Untersuchungen der vergleichenden Anatomie der Wirbelthiere," 1864–1872; "Grundzüge der vergl. Anatomie," Leipzig, 1870; and "Lehrbuch der Anatomie des Menschen," Leipzig, 1883 (7th edition, 1899).

A. H. B.

Geissopermum.—*Pao Pereira Bark.* The bark of one or more species of *Geissospermum* (fam. *Apocynaceæ*), *G. lævе* Miers being the important one, used in Brazil as a febrifuge. Three alkaloids have been reported, *geisospermine*, *pereirine* (this is not the only alkaloid of this name), and *vellosine* (from *G. Vellosii* Allem). The drug and its alkaloids have been used experimentally, especially in Europe, but have found no accepted position in medicine.

HENRY H. RUSBY.

Gelanthum is a mixture of tragacanth, gum acacia, gelatin, glycerin, and water, with a little thymol. It is used as a basis for various medicinal substances intended for application to the skin.

R. J. E. SCOTT.

Gelatin.—GELATINUM. *Gelatin* has been defined by the British Pharmacopœia as "the air-dried product of the action of boiling water upon such animal tissues as skin, tendons, ligaments, and bones." It appears in a variety of forms. That which has not been purified, made usually from animal matter which has partly decomposed, is *glue*. When purified by special processes it becomes *sparkling*. It usually occurs in sheets which have been dried upon coarse matting, but frequently in narrow strips cut from such sheets (*shredded gelatin*). Gelatin should be almost or quite colorless and transparent, without odor, and nearly tasteless, and should contain only traces of sulphur, which is apt to be present in excessive amount, as a result of the treatment in bleaching. Dissolved in 50 parts of hot water, it should yield a firm jelly on cooling. The aqueous solution is precipitatd by tannin, but not by alum, subacetate of lead, or ferric chloride T. S. Gelatin is soluble in acetic acid, but not in strong alcohol or ether. It has no medicinal activity, but is a nutrient of the albuminoid class, used in the diet of invalids and in the kitchen generally. Its chief use in medicine is, strictly speaking, pharmaceutical, for the manufacture of the well-known soft and hard gelatin capsules and for the coating of pills.

Gelatose is gelatin which, as a result of certain changes, especially those of bacterial causation, can no longer be gelatinized. HENRY. H. RUSBY.

Gels.—These are colloids which under certain conditions solidify in a gelatinous form containing considerable water. Only certain colloids can occur in the form of gels. Certain gels are spontaneously formed in sufficiently concentrated solutions (silicic acid, certain metallic hydroxides) and these do not redissolve in water. Other gels like gelatin and agar-agar are formed on cooling the hot concentrated solutions and are again soluble in water. According to some authors the gel formation of gelatin is to be regarded as a segregation process whereby a separation into two fluids occurs, one of which solidifies. Freed from water, gels show a special ability to take up water which is brought about by different processes which are included in the ordinary term imbibition; See *Colloids*.

F. P. UNDERHILL.

Gelsemium.—Yellow Jasmine, Yellow Jessamine. "The dried rhizome and roots of *Gelsemium sempervirens* (L.) Ait. f. (fam. *Loganiaceæ*)," U. S. P. The yellow jessamine of the Southern States is a pretty climbing shrub, with a large woody rhizome, and numerous fine roots, and slender, smooth, twining, purplish stems. It has dark green, glossy, lanceolate, entire, evergreen leaves, growing opposite to each other and bearing in their axils solitary or clustered flowers. The latter are large, sweet-scented, bright yellow, and slightly irregular. Calyx small, of five pointed sepals; corolla funnel-shaped, with a slightly oblique, five-lobed border; stamens five, perigynous. Fruit an oblong, flattened, drooping pod; seeds margined. This is one of the most attractive flowers in the Southern States. It grows abundantly from Virginia

Fig. 2694.—Yellow Jasmine.

southward, in woods, and mounts to the tops of tall trees. The flowers, which appear in the spring, load the air with their sweet odor.

Of course, so conspicuous a plant was early noticed; in fact, it was carried to England as an ornament in the first half of the seventeenth century. Its poisonous properties were also early known, but its medicinal employment is of rather recent date.

Description.—Rhizome cylindrical, short-flexuous, elongated or cut in sections of variable length, mostly from 0.5 to 1.5 centimeters ($\frac{1}{5}$ to $\frac{3}{5}$ in.) and occasionally 3 centimeters (a little more than an inch) in diameter, the roots much thinner, a few elongated, unbranched, coarsely hair-like tough rootlets usually attached; externally of a light yellowish-brown, commonly with some purple or purplish-brown longitudinal lines or patches, or occasionally deep purple-brown with yellowish-brown, fine ridges; heavy, hard, and tough; internally yellowish-white; fracture of the rhizome splintery, the roots breaking with half the fracture transverse, the other oblique or short-splintery; bark thin, closely adhering, that of the rhizome with fine, silky bast fibers, the wood porous, with numerous fine medullary rays; odor peculiar; taste slightly aromatic, bitter.

Composition.—It contains two alkaloids, *Gelsemine* ($C_{49}H_{63}N_5O_{17}$), crystalline, but inert upon the human subject, and *Gelseminine* ($C_{12}H_{14}NO_2$), which, like its salts, is amorphous, occurring as a white powder, soluble in alcohol, not in water, and which is the active constituent. Gelseminic acid is a saponin-like substance. A little resin and volatile oil, with starch, are also present.

Action and Use.—Gelsemium is an active paralyzing poison, capable of killing both animals and man in small doses, expending its action upon the nervous system. It does not affect consciousness until near the end of fatal cases; sometimes, but not always, it produces convulsions, due apparently to respiratory interference. Reflex excitability is increased at first, afterward diminished, while its paralyzing effect upon the motor columns steadily increases to the end. Death takes place by asphyxia, proceeding from central paralysis. It depresses or paralyzes the nerve endings to a less extent, and less promptly than the centers. Locally, and to a less extent systemically, it dilates the pupil and paralyzes the power of accommodation precisely like atropine. The following symptoms are observed in man after moderate doses: languor, debility, dizziness, disturbances of vision, dilatation of the pupils, paresis, especially of the flexors of the arm, and drowsiness. The poison appears to be quickly absorbed and promptly eliminated. This root, whose medicinal value is said to have been discovered by accident, has been considerably used in the South and West in the treatment of malarial and other fevers. It is occasionally employed in pneumonia and pleurisy as a depressant; in asthma, whooping-cough, etc., it is also indicated, but is not, in the East at least, very frequently given. In neuralgias it holds, perhaps, its place most firmly. It has also been useful when dilatation of the pupil is desirable, differing from atropine in the transientness of its effects.

Administration.—From gr. i.–iii. (0.06–0.18) of the powder, or the same measures of the fluid extract (*Fluidextractum Gelsemii*, U. S. P.) are suitable doses. The official 10 per cent. tincture is given in doses of ♏ viii.–xxx. (0.5–2.0).

It has been observed quickly to counteract mild disturbances due to overdoses of strychnin, and might be found efficacious as an antidote to the poison.

H. H. Rusby.

Geneva Lithia Springs.—Ontario County, New York.

Post-office.—Geneva.

Location.—Geneva.

The well-known Geneva lithia water is obtained from an artesian well 930 feet deep, which was bored in 1886. Issuing from a stratum of pervious rock defined by a layer of medieval sandstone sixty feet thick and a deep substratum of hard slate, the water is forced up by an internal pressure of 120 pounds to the square inch, and, if unimpeded at the surface, would form a fountain eighty feet high. The daily output is 350,000 gallons. The water is bright, clear, and sparkling, being agreeable to the palate and excellently adapted for table use. Recent analysis by Professor George A. Ferguson determined the following ingredients: Lithium chloride, magnesium sulphate, sodium sulphate, sodium chloride, sodium nitrite, ammonium chloride, potassium iodide, calcium sulphate, ferric oxide, sodium metaborate, sodium nitrate, potassium chloride, calcium phosphate, calcium bicarbonate, alumina and silica.

W. A. Pearson, Ph. G. Ph. C. analyzed the water also in 1908, and obtained practically the same results.

There is an entire absence of organic matter. The analysis shows a valuable lithia water, which possesses many excellent qualities. It may be classed as belonging to the lithiated-saline chalybeate variety. Aside from its strong impregnation with the bicar-

bonate and sulphate of lithia, it possesses enough of the sulphates of magnesium and sodium to give it laxative properties, and enough iron to make it a valuable ferruginous tonic when taken continuously. The water is used commercially, and has an extensive sale. It has the indorsement of many prominent physicians of the great Eastern cities. The water resembles that of a spring at Rippoldsau, in the Duchy of Baden, but is more heavily charged with iron andfee pp rhoshoric acid. It is extensively employed in anemic states and general debility, and in many of the conditions resulting from the so-called uric acid diathesis, viz., gout, dyspepsia, rheumatism, renal and vesical calculus, Bright's disease, and various skin disorders.

EMMA E. WALKER.

Genital Organs, Female.—The female organs of generation comprise the two genital glands or ovaries that produce the sexual elements, the two oviducts that convey them, the single uterus that protects them after impregnation, and the single vagina and vulva that serve as organs of copulation (see Fig. 2695)

Development.—Originally the male and female organs are indistinguishable, both being developed out

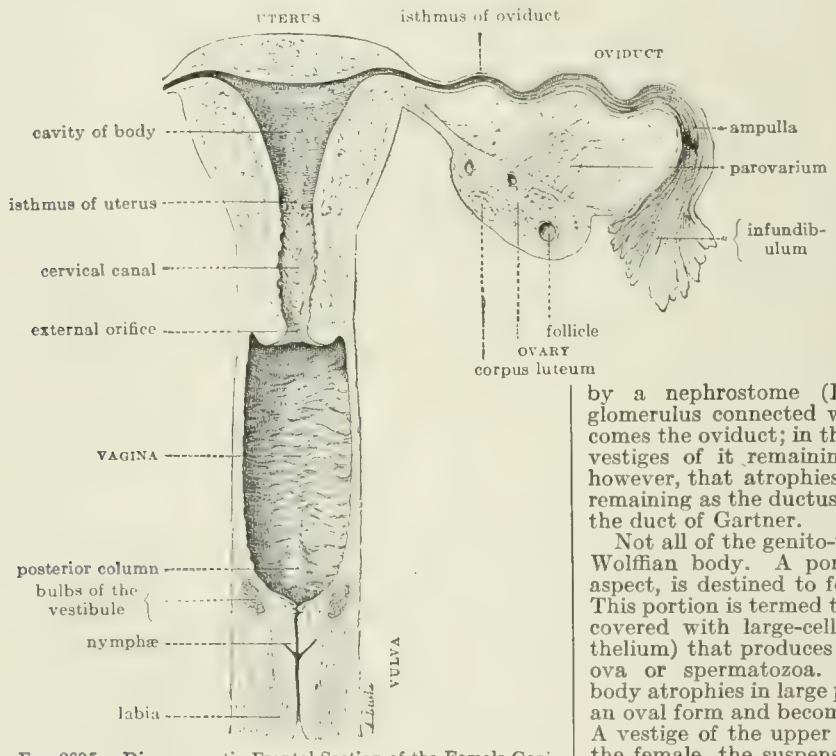

FIG. 2695.—Diagrammatic Frontal Section of the Female Genital Organs Passing through the Orifice of the Vagina. The oviduct and the ovary are lifted up. (Henle, modified by Rieffel.)

of an undifferentiated form. In many lower vertebrates the genital gland, the oldest and primary organ, empties its products (ova, spermatozoa) directly into the peritoneal cavity, whence they pass out by means of openings in the belly wall called abdominal pores. In the next higher forms these become associated with other organs of elimination and removal. Tubular canals termed *nephridia* communicate with the peritoneal cavity by means of a funnel-shaped opening or *nephrostome*, each having also a side branch that envelops an arteriole, thus forming a glomerulus and becoming an excretory duct for urine. The nephridia are, originally, arranged metamerically and are therefore sometimes called segmental organs. This arrangement gradually disappears by the increase of the canals which come to be assembled in distinct organs, successively developed; the *pronephros*, or head kidney, very simple in structure, the only functional urinary organ in amphioxus, persisting throughout life in some fishes, but disappearing early in man, and the *mesonephros*, primitive kidney or Wolffian body (Caspar Friedrich Wolff, 1735–94), which appears behind the pronephros, and which likewise consists of a series of nephridial tubules to each of which a glomerulus is attached, and which open into a duct (segmental duct, Wolffian duct) that, in common with the intestine, discharges into the cloaca, a short receptacle for excreta just above the anus.

In some fishes and amphibians the Wolffian body remains throughout life a functionally active urinary organ, and, in amphibians, carries on the duplicate function of urinary organ and genital duct. In the higher vertebrates the urinary function is taken on by the permanent kidney and the Wolffian body, as such, atrophies, portions of it remaining, however, as ducts for removing the sexual products.

The first rudiment of the genito-urinary apparatus in the genito-urinary ridge (Fig. 2696, *P. gén.*), a thickened, longitudinal band of epithelium that appears in the embryo of the fifth week near the spine and the primitive mesentery. This gradually increases in size, assumes an oval form, and detaches itself from the body wall as the Wolffian body (Fig. 2697, *R.pr.*) with its excretory duct (Fig. 2697, *c.w.*). Close beside this duct and following the same general course there develops a second tubule, Müller's duct (Johannes Müller, 1801–58) (Fig. 2698, *M*). It has a nephridial character, opening into the abdominal cavity by a nephrostome (Fig. 2698, *m'*), but has no glomerulus connected with it. In the female it becomes the oviduct; in the male it soon atrophies, only vestiges of it remaining. It is the Wolffian duct, however, that atrophies in the female, a trace of it remaining as the ductus epoophori longitudinalis, and the duct of Gartner.

Not all of the genito-urinary ridge goes to form the Wolffian body. A portion of it, along its ventral aspect, is destined to form the genital gland proper. This portion is termed the genital ridge or fold, and is covered with large-celled epithelium (germinal epithelium) that produces the essential sexual elements, ova or spermatozoa. In mammals, the Wolffian body atrophies in large part, the genital ridge assumes an oval form and becomes either an ovary or a testis. A vestige of the upper part of the ridge becomes, in the female, the suspensory ligament of the ovary; a vestige of the lower end becomes, in the male, the gubernaculum of the genital gland (ligamentum genitoinguinale), which, in the female, becomes attached to Müller's duct where the latter crosses over it, and thus becomes divided into the ligament of the ovary and the round ligament of the uterus, which pass respectively from the ovary to the uterus, and thence to the groin.

As the Wolffian and Müllerian ducts converge from either side toward the median line, they become united in a common cord, the genital cord, and, before reaching the cloaca, the Müllerian ducts blend in a single passage which, by enlargement and thickening of the walls, becomes the uterus and the vagina. Occasional traces of the Wolffian duct are found

along the sides of these organs, forming the so-called duct of Gartner, described by the Danish anatomist Gartner in 1822 in the sow, but previously noted in 1681 by Malpighi in the cow.

The genito-urinary ridge, like the rest of the walls of the body cavity, is covered over with peritoneum. As

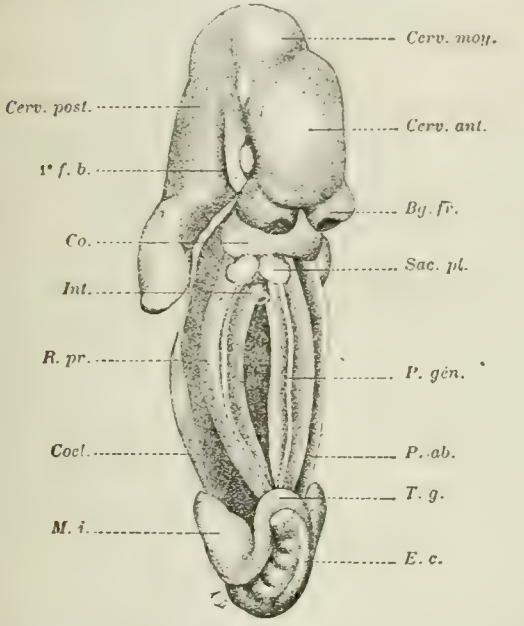

Fig. 2696.—Human Embryo during the Fifth Week. The anterior wall of the trunk has been removed: the Wolffian body exposed. (Kollmann.) *Cerv. ant., moy., post.*, Forebrain, midbrain, and hindbrain; 1° *f.b.*, first branchial cleft; *Bg. fr.*, frontal process; *Co.*, heart; *Sac. pl.*, pulmonary diverticulum; *Coel.*, cœlom; *P.ab.*, lateral wall of the abdomen; *M.i.*, rudiment of the lower extremity; *P.gén.*, genital ridge; *R.pr.*, Wolffian body; *Int.*, intestine; *T.g.*, genital eminence; *E.c.*, caudal extremity.

the Wolffian body becomes detached it is still held to the walls by a fold of peritoneum—the *mesonephridium* of Waldeyer, which invests both the free portions of the Wolffian and the Müllerian ducts and the upper

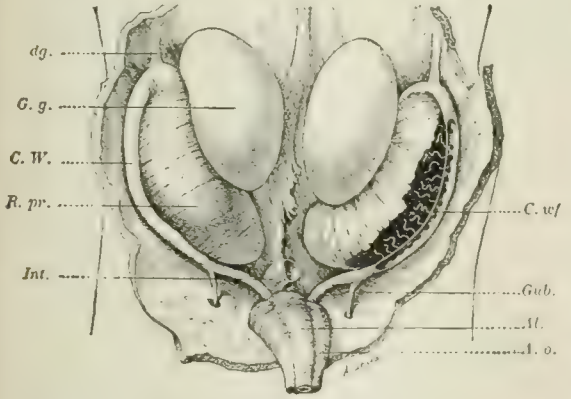

Fig. 2697.—Wolffian Body and the Genital Gland. Human embryo 17 mm. long. (Kollmann.) *L.dg.*, Suspensory ligament; *G.g.*, genital gland; *C.W.*, Wolffian duct; *R.pr.*, Wolffian body, mesonephros, or primitive kidney; *Int.*, intestine; *A.o.*, umbilical artery; *Al.*, duct of the allantois; *Gub.*, gubernaculum of the genital gland or ligamentum genitoinguinale; *C.wf.*, canaliculi of the Wolffian body.

part of the genital cord (Figs. 2699, 2700, and 2701). The mesonephridia of opposite sides are therefore continuous with each other across the median line, and, as the Wolffian body atrophies and the uterus develops, there is thus formed the large transverse fold of peritoneum known as the broad ligament of the uterus, which invest the remains of the Wolffian body, the ovaries, the oviducts, and the upper part of the uterus.

A change in the position of the ovary occurs, arising from the difference in the growth of the ovarian attachments and that of the general body. This,

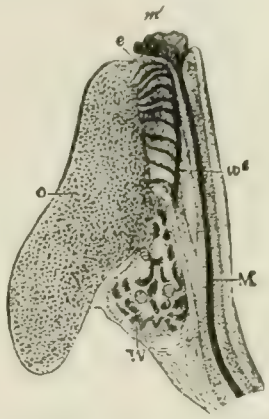

Fig. 2698.—Longitudinal Section through Genito-urinary Ridge of Human Female Embryo of about Fourteen Weeks (3.5 in. long). (Waldeyer.) *o*, Ovary, *e*, tubes of upper part of Wolffian body forming the epoophoron; *W*, lower part of Wolffian body, forming paroophoron; *w'*, remnant of Wolffian duct; *M*, Müller's duct; *m'*, its funnel-shaped peritoneal opening or nephrostome.

the "descent of the ovary," is analogous to the descent of the testis in the male, but is not usually so complete, because of the interposition of the uterus by the attachment of the gubernaculum thereto (Fig. 2701). It places the organ in the pelvic cavity. Rarely it has been known to proceed along the course of the round ligament of the uterus and reach the interior of the labium majus, the analogue of the scrotum of the male.

In the female there develop, from the deeper layers of the germinal epithelium, cells of two kinds, one of which, large, with reticular nuclei, becomes the sexual

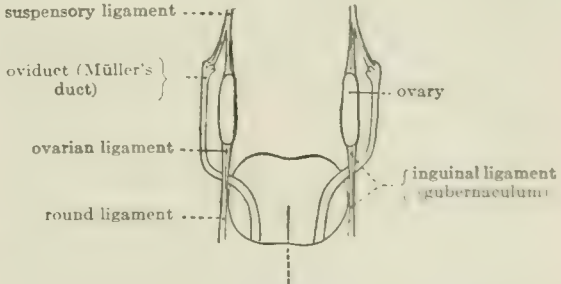

Fig. 2699.—Scheme showing the Genesis of the Primitive Broad Ligament or Mesonephridium. From a human embryo 5.5 cm. long. (Fredet.) Müller's duct should pass *over* the inguinal ligament. The mesonephridium stretches longitudinally from the diaphragm to the inguinal region on each side of the pelvic cavity, ensheathing the structures shown in the diagram.

cells or ova; others, smaller and more cubical, surround the former and separate them from the invading mesodermal connective tissue. The sexual cells form, at first, chaplet-like strings known as egg columns or Pflüger's tubules (E. F. W. Pflüger, 1829–1910); later these are broken up, each sexual cell forming, with its investing elements, a primitive follicle or ovisac (Fig. 2702).

The cloaca or common passage into which the in-

testine and the genito-urinary ducts discharge is at first closed from the exterior by a thin partition termed the cloacal membrane, extending from the rudimentary coccyx forward, and marked by a slight

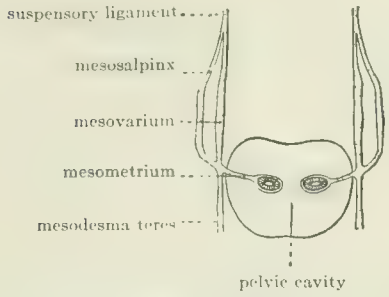

Fig. 2700.—Diagram of Section of the Mesonephridium at its Base. (Fredet.) The duct of Müller descending into the pelvic cavity receives a primitive mesometrium.

depression of the exterior surface known as the cloacal fossa (Fig. 2703). In front of this there forms a conical outgrowth known as the genital eminence (*eminentia genitalis*) which increases rapidly in size

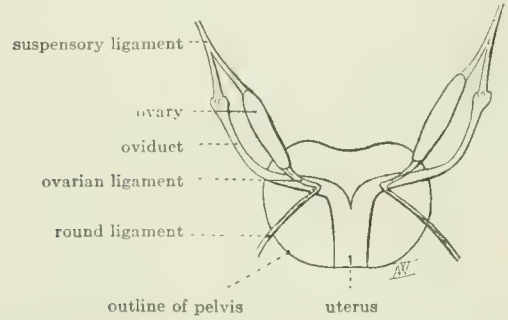

Fig. 2701. Diagram showing Formation of the Permanent Broad Ligament. (Fredet.) The mesodesma suspensorium (peritoneum around suspensory ligament), the mesovarium, the mesodesma teres (peritoneum around round ligament), and the mesosalpinx, which form at first a continuous fold on either side (the primitive broad ligament) are drawn together and united across the middle line (mesometrium) by the union of the ducts of Müller. The oviduct should pass *over* the round ligament.

and forms at its top a rounded projection (*tuberculum genitale*) that becomes, later, either the clitoris or the glans penis (Fig. 2703). Behind this occurs a slit-

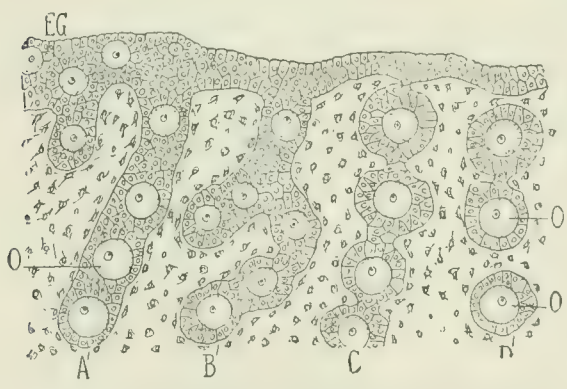

Fig. 2702.—Egg Columns or Pflüger's Tubules, showing Phases in the Production of the Ovisacs. (Duval.) *EG*, Germinal epithelium with the primordial ovisacs; *A*, egg column or tubule of Pflüger in its primitive state; *B* and *C*, tubules assuming a chaplet-like form; *D*, breaking up of the chaplet; the ovisacs become independent; *O*, *O*, *O*, ova.

like depression of the cloacal membrane, the urogenital cleft (*rima genitalis*) bounded on each side by two folds, the inner genital folds (*plicæ genitales*), which

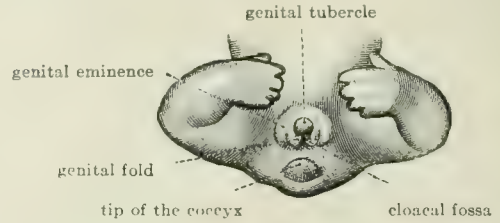

Fig. 2703.—The External Genital Organs of a Fetus of Seven Weeks. (Toldt.) The urinary and genital canals discharge into a common opening, the cloacal fossa.

finally become, in the female, the labia minora and the frenulum of the clitoris.

In the mean time the cloaca becomes divided, by means of a septum (*septum urogenitale*) formed by two folds that grow in from the sides, into two com-

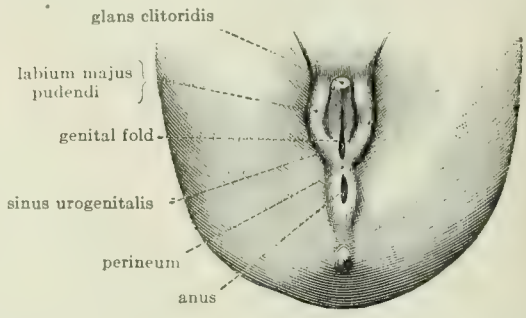

Fig. 2704.—The External Genitals of a Female Fetus at the Middle of the Third Month (5.6 cm. long). (Toldt.) Complete separation of the anus from the urogenital sinus.

partments, a ventral one, the urogenital sinus, and a dorsal one which becomes the rectum (Fig. 2704). This division affects also the cloacal membrane, the ventral portion of which now closes in the urogenital cleft, and is known as the urogenital membrane.

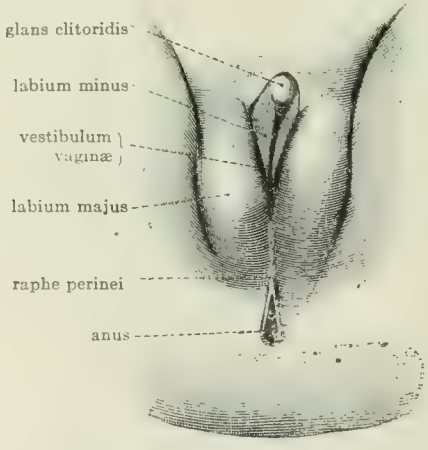

Fig. 2705.—The External Genitals of a Female Fetus at the End of the Fifth Month (11.5 cm. long). (Toldt.)

This soon thins away and disappears so that the cleft opens immediately into the urogenital sinus.

There now arise, at the base of the genital eminence on either side, two rounded folds, the outer genital or labio-scrotal folds (*tori genitales*), which extend

backward as far as the anus and join each other in front around the genital eminence. These become the labia majora of the female or the scrotum of the male (Fig. 2705).

The Ovaries.—*Etymology.*—From the Neo-Latin *ovarium*, a derivative from *ovum*, an egg. Greek, *ὠοφόρον*, from whence many compounds arise, such as *oophorectomy, oophoralgia, oophoritis*, etc. French, *ovaire;* Italian, *ovario;* German, *Eierstock*. The name was first used in 1667 by the Danish anatomist, Nil Stensen, who supposed the ovisacs to be ova. The ancients, recognizing their analogy to the male genital glands, called them testes muliebres.

History.—The Alexandrian anatomists probably knew them, and they were described by Soranus of Ephesus (A. D. 117) who considered them as useless

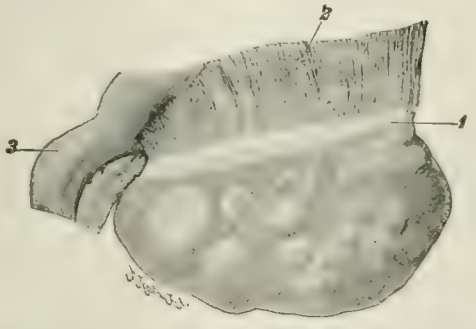

Fig. 2707.—The Human Ovary. (Nagel.) 1, Farre's line; 2, mesovarium; 3, oviduct and fimbria ovarica.

bodies, and also by Galen, who supposed them to secrete a female semen, very fluid and "cold," which was conveyed to the uterus by the oviducts. Athenæus (A. D. 69) denied this, as did afterward Fallopius. It was, however, generally held up to the time of De Graaf, who, in 1672, insisted that their proper use was to generate ova, to nourish them, and to bring them to maturity.

The ovisacs were known and mentioned under various names by Vesalius, Fallopius, Bartholinus, and others. Jan Van Horne, professor at Leyden, was the first to call them *ova*, and thus emphasize the egg-producing function of the ovary. The veritable ovum was not discovered until 1827, when von Baer described it.

Definition.—The organs of the female, in which are developed the ova, or essential sexual products. They differ from ordinary secreting glands in that they do not form new products, but merely develop and mature structures that already exist in them, in a rudimentary condition, at birth.

Form.—The human ovary (Fig. 2706, 4) is a solid, al-

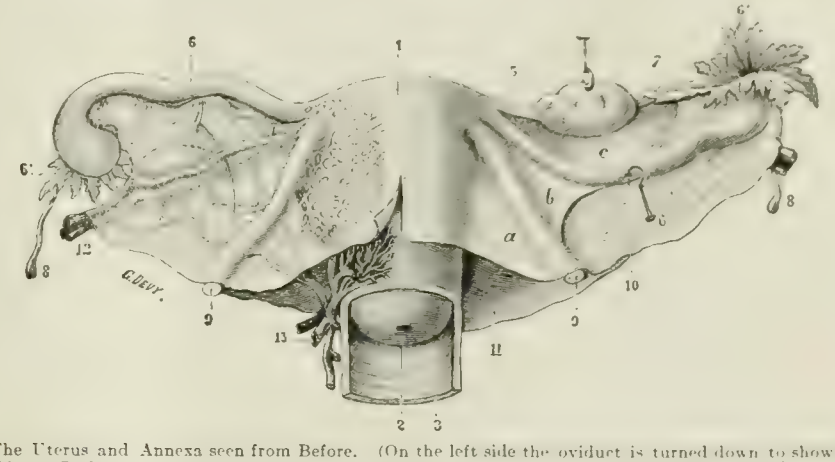

Fig. 2706.—The Uterus and Annexa seen from Before. (On the left side the oviduct is turned down to show the ovary which is slightly raised.) 1, Body of the uterus, covered by peritoneum; 2, its cervix, with the external orifice; 3, vagina, its anterior wall removed; 4, left ovary; 5, ligament of the ovary; 6, oviduct, with 6′, its infundibulum; 7, ovarian fimbria and tuboovarian ligament; 8, hydatid of Morgagni; 9, round ligament; 10, broad ligament, with *a*, *b*, *c*, its three divisions or "*ailerons*"; 11, posterior layer of the broad ligament; 12, ovarian vessels; 13, uterine vessels.

mond-shaped body, about four centimeters long by two centimeters wide and one centimeter thick ($1\frac{1}{2}\times\frac{3}{4}\times\frac{1}{2}$ in.) in the adult (Fig. 2707); in childhood and old age considerably less. It may vary from this typical form and be disc-like, cylindrical, triangular, or irregular. The right ovary is slightly larger than the left. The attached edge of the ovary is nearly straight, the free edge usually curved. Its extremities, also called poles, are distinguished as inferior, or uterine, and superior, or tubal, the latter being attached to the infundibulum of the oviduct.

Color.—This is a soft, dull, reddish gray, like that of a mucous membrane, easily distinguished from the smooth, glistening appearance of the neighboring organs due to their peritoneal covering. The peritoneum, forming the broad ligament and the mesovarium, abruptly ceases at the attached edge of the ovary at a crenulated line (Fig. 2707, 1), Farre's line (Arthur Farre, physician of London, *circa* 1840), and, the organ presents its bare surface in the abdominal cavity, being the only one that, in the strict sense of the word, is within the peritoneal sac. The reddish tint increases during the hyperemia preceding menstruation and decreases after the menopause.

Consistency.—Although in youth quite dense and resistant to pressure, the development of the vascular tissue in the ovaries is such as to make them slightly spongy, and at puberty they are not as firm as the testes of the male. Their density increases after the menopause. Before menstruation the surface is smooth, but afterward the development and rupture of the ovisacs produce on the surface elevations and depressions that have been compared to those of a peach stone or to the convolutions of the brain (*ovarium gyratum*, Abel).

Weight.—This naturally varies with the size of the ovary, being 50–60 centigrams at birth, 4 or 5 grams at puberty, 6–8 grams in the adult, and decreasing gradually to a gram or less in old age. It is thought that a rapid increase of weight occurs from the hyperemia of the menstrual period.

Attachments.—The cavity of the pelvis is transversely divided into two compartments by the broad

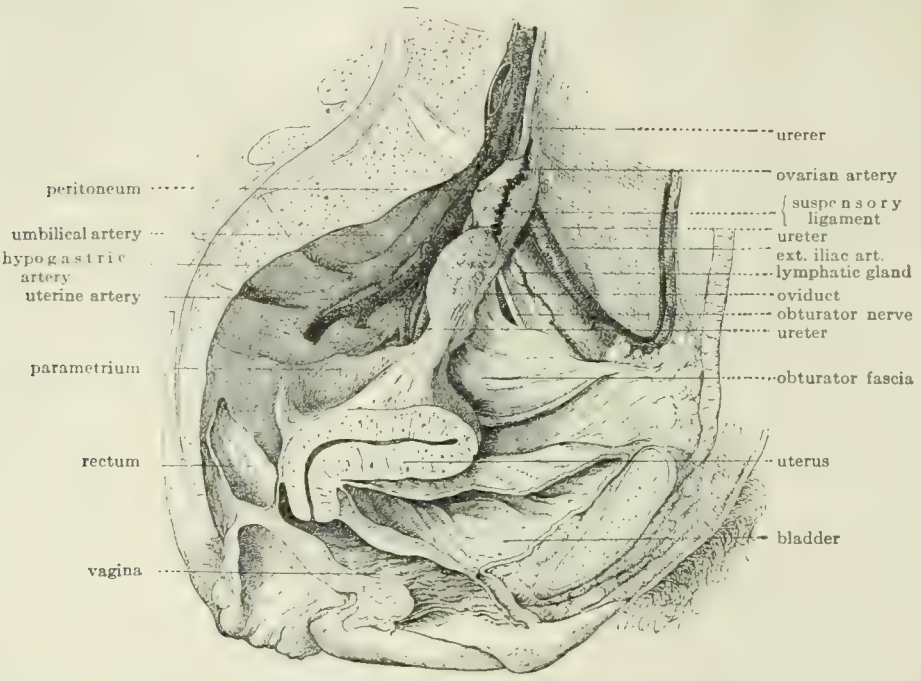

Fig. 2708.—Median, Antero-posterior Section of the Pelvis of an Adult Female. (Rieffel.) The uterus is low and very near the coccyx. The anus is gaping, the vagina open and the bladder much spread out. The peritoneum is removed in front and behind the suspensory ligament of the ovary, to show the subjacent organs. The ovary is in place.

ligament, a fold of peritoneum that encloses the uterus and the oviducts. The ovaries are attached edgewise to the postero-superior surface of this fold by a short peritoneal duplicature termed the *mesovarium* (Fig. 2706, *c*, Fig. 2707, 2), which is continued upward from the superior pole of the ovary as a triangular band, the suspensory ligament (Fig. 2708), containing the ovarian vessels and nerves, some unstriped muscular fibers, and a long fimbria from the extremity of the oviduct (Fig. 2706, 7). At the inferior pole is attached the ligament of the ovary (Fig. 2706, 5), a fibroareolar structure containing some muscular fibers, that extends in the folds of the broad ligament to the uterus. The ovary has considerable mobility, turning, hinge-like, around its mesovarian margin, and is also subject to displacement by a stretching of its attachments and the dragging of the broad ligament itself, which is affected by the position of the uterus.

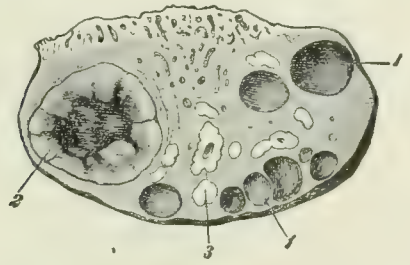

Fig. 2709.—Section of a Human Ovary. (Nagel.) 1, Ovisac; 2, corpus luteum; 3, corpus albicans (several such are seen on the surface of the section).

Situation.—Varying greatly in weight under different normal conditions and at different periods of life, it is not surprising to find the ovaries varying also in position. This is influenced by a variety of conditions, such as posture, pregnancy, the state of repletion of the bladder and rectum, and inflammatory conditions which may cause adhesions between the ovary and the surrounding viscera. However, in the adult female, when the uterus is normally placed, the ovary, if not affected by repeated pregnancies or by pathological conditions, usually lies in a nearly vertical position (Fig. 2708) in a shallow depression, the ovarian fossa, on the lateral wall of the pelvis, in the acute angle made by the hypogastric artery externally, and the ureter and uterine artery internally. Anteriorly it is sustained by the shelf-like broad ligament. It is usually somewhat displaced during the first pregnancy. The oviduct, bending around its lateral and medial surfaces and upper end, leaves a pouch-like depression of the broad ligament between itself and the ovary, which is termed the bursa ovarica. The external iliac vessels and the psoas muscle lie to the outer side of the ovarian fossa, and under its floor,

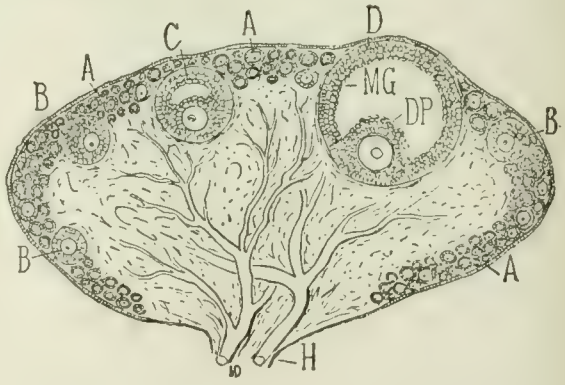

Fig. 2710.—Diagrammatic Section of the Ovary showing its Cortical or Ovigenous Layer, Formed of Ovisacs in various Stages of Evolution. (Duval.) *A*, *A*, *A*, Primordial ovisacs; *B*, *B*, *B*, ovisacs further developed; *C*, ovisac approaching maturity; *D*, ripe ovisac with its proligerous disc (*D P*) containing the ovum; *M G*, membrana granulosa; *H*, hilum of ovary.

covered by peritoneum and surrounded by subperitoneal fat, run the obturator vessels and nerve, these separating the ovary from the obturator internus muscle. In a standing position the mesovarian margin looks forward and outward, but is concealed by the oviduct. Its free margin looks inward and backward toward the rectum and is in relation with the ureter. Often the ovary is not easily seen upon casual inspection of the pelvic contents. A line connecting the two ovaries lies behind the body of the uterus when

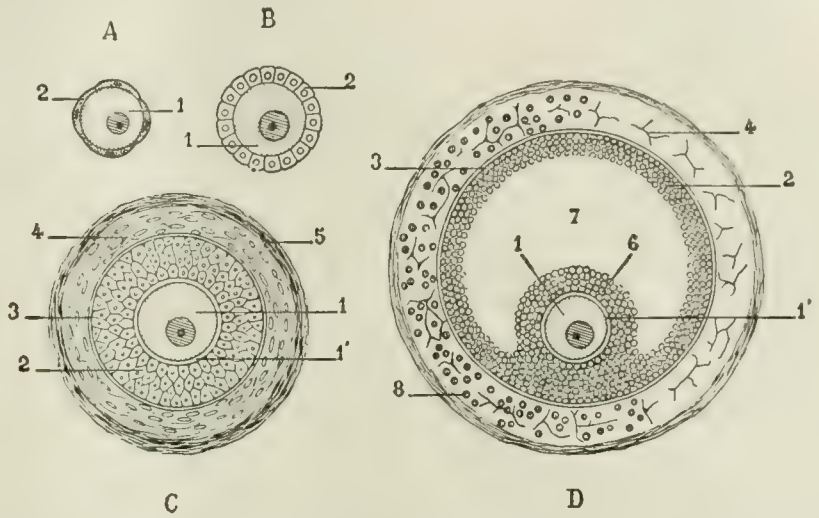

Fig. 2711.—Ovisacs. A, Primordial ovisac; *B*, *C*, *D*, ovisacs at various stages of their development (diagrammatic). (Testut.) 1, Ovum; 1′ (*C*), vitelline membrane; 2, membrana granulosa; 3, membrana propria; 4, tunica propria; 4′ (*D*), reticular tissue replacing the tunica propria; 5, tunica fibrosa; 6, cumulus oophorus; 7, liquor folliculi; 8, leucocytes in the reticular tissue (shown only at left of *D*).

that organ is in its normal position. Therefore, when the ovary, by increasing in weight, stretches its attachments, if not adherent it usually falls into the recto-uterine excavation.

Referred to the exterior of the body the site of the ovary is usually behind a point on the abdominal wall about two inches medially from the anterior superior spine of the ilium. The sagittal plane that cuts it is midway between that spine and the symphysis. The frontal plane tangent to the promontory either cuts it or passes close behind it, while the frontal plane corresponding to the ischiatic spines passes considerably behind it. Horizontally, it is above the lesser sciatic foramen and on a level with the infrapyriform foramen and the upper margin of the acetabulum (see article *Pelvis*).

The ovary may be reached by both vaginal and rectal examination. In the vaginal method the patient is placed in dorsal decubitus with the thighs flexed, and one or more fingers, pushed into the posterior cul-de-sac of the vagina, explore the pelvic wall. With the other hand the surface of the abdomen is depressed over the region above described as the site of the ovary. The medial border of the psoas may usually be made out as a rounded ridge, and the ovary will be found to the inner side of this, and may usually be grasped between the internal and external fingers.

Structure.—A section of the ovary (Figs. 2709, 2710) shows that besides its investing epithelium (derived from the germinal epithelium of the embryo) its substance, or stroma, may be divided into an external cortical, or ovigenous layer, crowded with small round bodies, varying in size from that of a mustard-seed to that of a pea; and a medullary layer rich in vessels and nerves, with spindle-shaped connective-tissue cells, some elastic fibers and plain muscular tissue. The round bodies are the ovisacs (Figs. 2709, 2710, 2711—Graafian or ovarian follicles, from the Dutch anatomist, Regnier de Graaf, 1641–73), already mentioned as derived from the epithelial layer. The smaller ones (primordial ovisacs, *AAA*, Fig. 2710; *A*, Fig. 2711) contain no fluid, but the larger ones are distended by an albuminous liquid, the *liquor folliculi* (7, Fig. 2711). Within each ovisac is a large sexual cell or ovum, surrounded by a layer of smaller cubical cells that form an epithelial investment termed the membrana granulosa. The larger ovisacs have a distinct connective-tissue investment (*theca folliculi*) derived from the stroma and richly supplied with blood-vessels. This consists of two layers, the *tunica externa* and *interna* (4, 5, Fig. 2711). The former blends with the surrounding stroma; the latter is composed of cells resembling those of embryonal connective tissue, many of which are large, rounded, and infiltrated at maturity with yellow granulations (4′, Fig. 2711). These have been termed lutein cells, and are believed to be connective-tissue cells transformed for the nutrition of the follicles.

The liquor folliculi is secreted from the membrana granulosa, whose cells multiply and come to be arranged in several layers, surrounding the ovum, which remains single, always attached to the side of the follicle by an accumulation of the cells (*cumulus oophorus*, Fig. 2711, 6.) The ovisac continues to swell, both by the multiplication of the granulosa and by the increase of fluid, and thus gradually pushes its way outward and appears on the surface of the ovary as a fluctuating vesicle. Blood-vessels ramify abundantly on its walls, except at a superficial pole called the *stigma*, where they are wholly wanting. It is at this spot, and probably from some increase of vascular tension, that the vesicle finally ruptures. Preceding this the granulosa attaching the ovum to the wall of the vesicle becomes softened, probably by invasion of lutein cells, and, at the rupture, the ovum with a portion of the cumulus adhering to it is thrown out of the sac. Some slight hemorrhage from ruptured capillaries occurs into the empty sac. This act is known as *ovulation*.

At birth the ovary is crowded with primordial ovisacs. Waldeyer estimates their number at 100,000, while some observers place it much higher, Sappey noting a case in which they exceeded 1,000,000. Most of them degenerate, however, there being not more than 30,000 or 40,000 at puberty, and but few of these ever come to maturity. Olshausen could

find but from 50 to 100 follicles visible to the naked eye in an adult female. They entirely disappear after the menopause.

Corpora Lutea.—Some of the follicles that thus abort acquire a certain degree of development before

Fig. 2712.—Diagrammatic Section of a Recent Corpus Luteum. (Balbiani.) *a*, Ovarian stroma; *b*, tunica fibrosa or external layer of the ovisac; *c*, internal tunic hypertrophied and folded; *d*, remains of the membrana granulosa. *e*, vessel supplying the ovisac.

disappearing, and, without rupturing, form, apparently by a multiplication of the lutein cells, a yellowish body known as a *corpus luteum* (*corpus luteum atreticum*). In completely matured and ruptured follicles, the formation of a corpus luteum is much more marked (Fig. 2712). It is produced by a hypertrophy of the walls of the follicle, these becoming imbricated and vascularized about the central clot, which contracts. The folds finally become united with each other and a yellowish body is formed, having a size considerably greater than that of the original ovisac. If pregnancy intervenes after the discharge of the ovum, the corpus luteum persists during a greater part of the period, and usually attains a great size (*corpus luteum graviditatis, corpus luteum verum*); but if there is no pregnancy it begins to atrophy, and disappears in the course of two or three weeks (*corpus luteum menstruationis, corpus luteum spurium*). It was formerly believed that certain information regarding a pregnancy could be obtained from examination of the corpora lutea, but this is not strictly correct, for the structure of the two is identical, and cases have been noted in which the corpus luteum of menstruation equalled in size that of pregnancy.

On microscopic examination it is found that a corpus luteum is made up of very large cells with rounded angles, having an appearance very much like that of liver cells. These are lutein cells, so called from granules of a yellow substance found within them, associated with fat and known as lutein. The tunica externa of the theca remains, and there develop from it radiate septa that extend throughout the body to a central nucleus, representing the site of the original clot, where crystals of hematoidin are often found. By fatty degeneration and absorption the lutein cells finally disappear; the connective tissue contracts to a whitish mass (*corpus albicans*), and finally to a fibrous remnant (*corpus fibrosum*), which is at last also removed by hyaline degeneration.

Observers are not fully in accord as to the origin of the lutein cells. Sobotta, after very careful observations on the mouse, concludes that they are of epithelial origin, arising from a hypertrophy of the granulosa (Fig. 2713), and in this he is supported by Bischoff, Pflüger, and many others. Another view is that they are of connective-tissue origin, arising from the cells of the tunica interna, and that the granulosa wholly disappears. Observations on abortive ovisacs seem to support this view, which is warmly defended by Clark, Minot, Paladino, and others. The matter cannot be definitely settled until human material, showing the earlier stages, is more fully investigated.

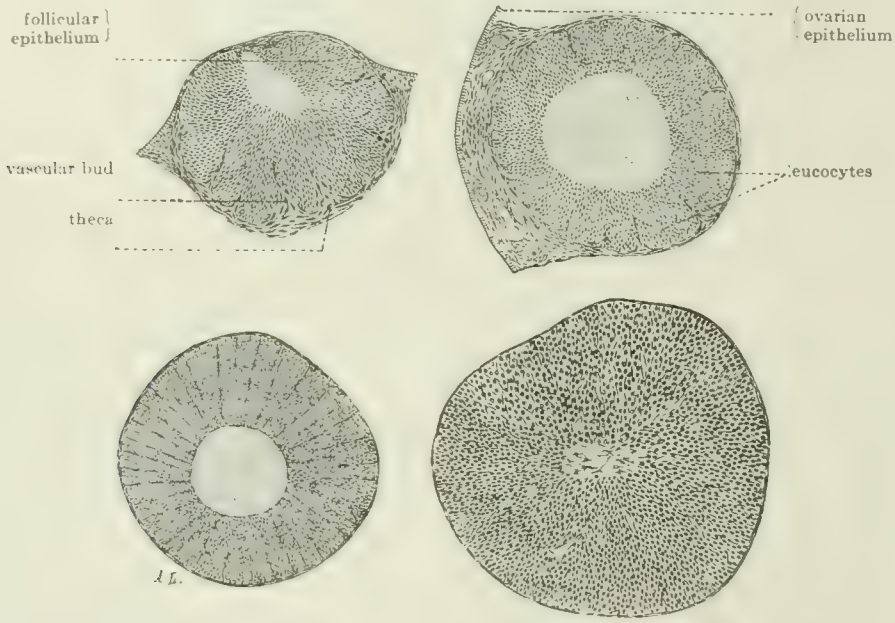

Fig. 2713.—Formation of the Corpora Lutea, according to Sobotta. Four successive stages in the mouse. *A*, Vascular budding of the tunica interna invading the hypertrophied follicular epithelium; *B*, the vascular buds converge toward a central cavity; between them the follicular cells, which are rapidly multiplying, are arranged in columns; among these cells leucocytes are found. *C*, A more advanced stage; the columns are now narrower and the trabeculæ more numerous. *D*, The central cavity is now occupied by a gelatinous connective tissue; the trabeculæ, by anastomosing with each other, have destroyed the columnar arrangement of the lutein cells.

The function of the corpus luteum has been the subject of much discussion. Born, struck with the resemblance of its structure to that of the suprarenal capsule, advanced the hypothesis that the organ is a ductless gland that modifies the blood so as to produce the changes in the uterus necessary for the encapsulation and subsequent nutrition of the ovum. He argued that the corpus luteum is much larger than would be necessary for the mere restoration of the ovarian tissue, and that the growth of the uterus during pregnancy is not due to distention by the grow-

ing ovum, but is accompanied by profound structural changes, which may be initiated without the ovum being in the uterus at all, as in the well-known case of extrauterine pregnancy. Further, mammals that have a placenta which becomes firmly attached to the uterus have a well-developed corpus luteum, while the aplacental mammals (monotremes, marsupials) have only a rudimentary one or none at all. Fränkel and Cohn found that in rabbits the removal of both ovaries within six days after copulation always prevented pregnancy. According to this view, the corpus luteum of menstruation may have an effect upon the restoration of the uterus.

Clark and others contend that the organ is required to maintain the peripheral circulation and proper course into the pelvis through the suspensory ligament of the ovary, its long course being explained by the fact that the ovary was primitively an abdominal organ. It gives off a tubal branch that supplies the fimbriated extremity of the oviduct, ten to fifteen ovarian branches, and is continued to make a free, anastomotic loop with the uterine artery. During pregnancy, when it is greatly enlarged, it is an important supplementary source of supply for the rapidly growing uterus. The small ovarian branches penetrate the ovary along its attached border, the place of entrance, which also serves for veins, nerves, and lymphatics, being called the hilum. Their course is helicine or corkscrew-like, not only in the broad ligament, but also in the substance of the organ.

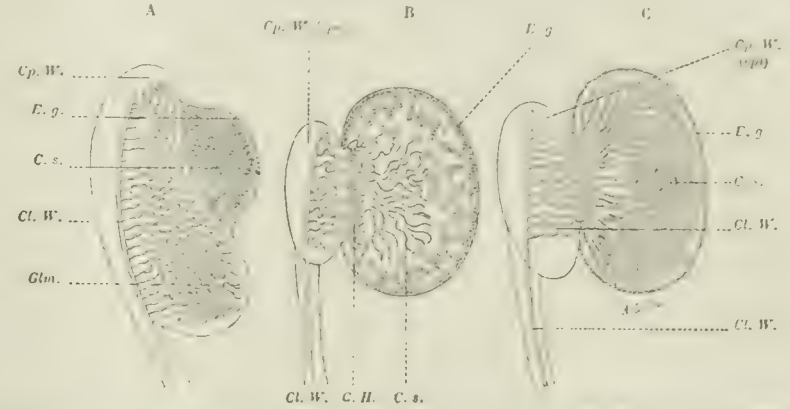

Fig. 2714.—Scheme Showing the Development of the Sexual Gland and its Ducts. (Mihalkovics.) *A*, Indifferent stage. *B*, female; *C*, male; *Cp.w.*, Wolffian body with the epoophoron (*epo*) and the epididymus (*epi*); *Cl.w.*, Wolffian duct; *C.s.*, sexual radiations; *Glm.*, Wolffian glomeruli; *C.H.*, body of Highmore (rete ovarii); *E.g.*, germinal epithelium; *V.eff.*, efferent ducts of the testis.

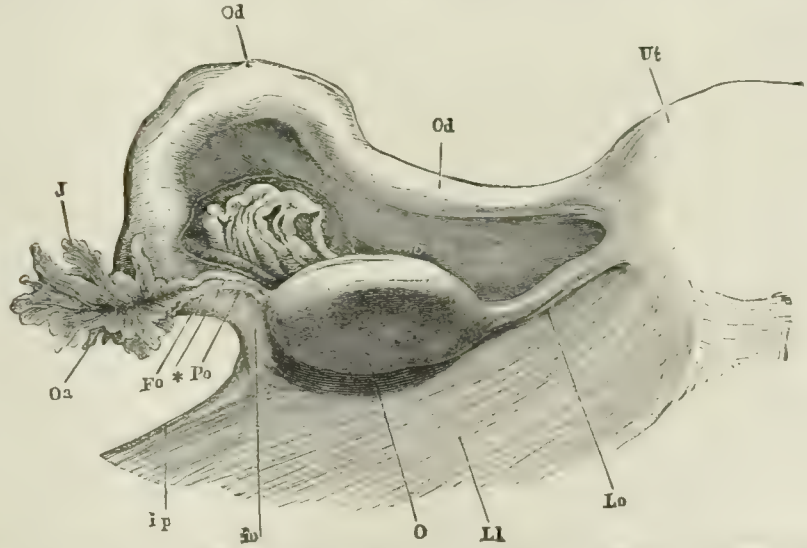

Fig. 2715.—View of Lateral Angle of Uterus with Broad Ligament from Behind. (Henle.) *Ut*, Uterus; *Ll*, broad ligament; *Od*, isthmus of oviduct; *Od'*, ampulla of oviduct; *J*, infundibulum; *Oa*, abdominal opening of oviduct; *Fo*, ovarian fimbria; *ip*, suspensory ligament; *Po*, epoophoron laid bare by removal of part of the posterior lamella of the broad ligament.

surface tension in the ovary by preventing the formation of cicatrical tissue at the point of discharge of the ovum. If each rupture of an ovisac were followed by a typical scar, the entire surface of the ovary would soon be reduced to inactivity.

Arteries.—The ovary is supplied by the ovarian artery, which arises from the abdominal aorta just below the renal arteries, and descends with a flexuous In the medullary portion they form the rich anastomoses which cause this to be named the vascular zone; and at the confines of the cortical and medullary portions they form imperfect arcades from which arterioles are given off which penetrate to the ovisacs and the corpora lutea and form a capillary network about them.

Veins.—These are large, sinuous, spiroid in char-

acter and accompanied by bands of smooth, muscular fiber like those of erectile tissue. In the hilum, mesovarium, and neighboring folds of the broad ligament the veins form a vascular protuberance called by Rouget the bulb of the ovary, and believed by him to have some function in ovulation. Leaving the broad ligament, the veins unite to form the pampiniform plexus and finally discharge into the uterine and ovarian veins.

Lymphatics.—These are very numerous. They originate in the stroma and about the ovisacs, some of the smaller sacs being often nearly surrounded by a lymph sinus. Converging to eight to ten trunks, they pass out at the hilum, accompany the vessels and discharge into glands situated in front of the aorta.

Nerves.—These are derived from a sympathetic plexus that is given off from the renal plexus and accompanies the ovarian artery. The exact terminations are imperfectly known. They have been traced to the walls of vessels, to smooth muscular fibers, to the surface epithelium, and to the tunica interna of the Graafian follicles.

Vestigial Structures.—There remain within the ovary, in the folds of the broad ligament and elsewhere, certain vestiges of the fetal condition of the organs that it is necessary to briefly mention. These are as follows:

The *epoophoron, parovarium,* or *body of Rosenmüller* (Fig. 2714, *B*, Fig. 2715) consists of six to twelve nearly parallel tubes containing a clear fluid, which are found within the folds of the mesosalpinx. They converge toward the hilus of the ovary, and may in young animals be traced into its substance (see Fig. 2714 *B, C.s.*). Toward the oviduct they end in a longitudinal canal, the remains of the Wolffian duct. They represent vestiges of the sexual part of the Wolffian body, and are homologous with the seminiferous tubules and vasa efferentia of the male.

The *paroophoron* is a similar series of tubes found in the broad ligament nearer the uterus, and representing the unused urinary part of the Wolffian body (*Glm, A*, Fig. 2714). They are of a yellowish color and usually disappear early.

Gartner's Canal.—This is the remains of the lower part of the Wolffian duct occasionally found in the wall of the uterus and vagina. It is homologous with the vas deferens of the male.

Hydatids of Morgagni.—In about twenty per cent. of subjects there is found connected with the infundibulum of the oviduct, usually with the ovarian fimbria, a small hollow cyst known as the hydatid of Morgagni. Similar structures may be found in the folds of the broad ligament in connection with the epoophoron. Their homologies and origin are obscure.

The Oviducts.—*Etymology.*—From the Neo-Latin *oviductus*, derived from the Latin *ovum*, an egg, and *ductus*, a leading, a passage. Greek, σάλπιγξ, from whence many compounds, such as *salpingitis, salpingotomy,* etc.; French, *oviducte, trompe uterine;* Italian, *ovidutto, tromba de Falloppio;* German, *Eileiter, Muttertrompete.* The name was first used by De Graaf, about 1672. The older anatomists styled them *vasa deferentia.* Often called the Fallopian tubes, from Gabriello Falloppio (1532–62), professor at Ferrara, Pisa, and Padua, who compared their expanded ends to that of a brazen *tuba* or trumpet. This name was first given them by Riolanus about 1618. In the nomenclature of the German Anatomische Gesellschaft they are known as the *tubæ uterinæ.* Some authors restrict the term oviduct to the genital passages of animals possessing no uterus. There seems no good reason for this, nor is it proper to anglicise the B N A term as uterine *tubes.*

History.—They were probably known to Herophilus (335–280 B.C.). Eudemus (290 B.C.) described the fimbriated extremity. Rufus of Ephesus demonstrated them in the sheep about A.D. 50. They were generally supposed to convey the product of the ovary, the hypothetical female semen. Fallopius showed that they did not closely connect with the ovaries, and considered that "fuliginous vapors" exhaled from the uterus through them into the abdomen. Others supposed them to be spiracles through which "spirits" could pass from the mother to the fetus.

Definition.—Paired trumpet-like structures, extending from near either ovary to the uterus, by which the mature ova are conveyed from the peritoneal cavity to the latter organ. They differ from the ducts of secreting glands in being detached from the organ whose products they convey.

Form.—The general shape of an oviduct (see Fig. 2695) is that of a gradually expanding, sinuous trumpet, extending laterally from either angle of the uterus, of which it appears to be a continuation. This is even more striking in the lower animals, in whom the fusion of the Müllerian ducts is not so complete, and who consequently possess a bicornuate uterus.

Divisions.—Starting from the uterine cavity we may distinguish (Figs. 2695 and 2706): (1) a uterine, intramural, or *interstitial* portion, passing through the walls of the uterus, in which the lumen of the duct is reduced to very small dimensions; (2) the *isthmus,* a narrow, comparatively straight portion, having no well-defined limit, but generally reckoned as about one-third the

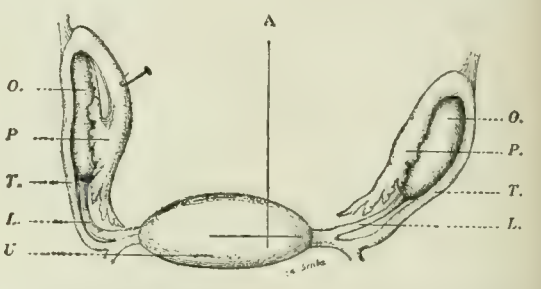

Fig. 2716.—Relations of the Ovary and the Oviduct. (His.) *O*, Ovary; *P*, infundibulum; *T*, oviduct; *L*, ovarian ligament; *U*, uterus. The annexa are held up by the suspensory ligament. The fundus of the uterus deviates somewhat from the median line.

length of the duct; (3) the *ampulla,* an enlarged, sinuous portion which terminates by (4) the *infundibulum* or *fimbriated extremity,* a funnel-shaped expansion surrounded by a fringe-like border by which the duct opens into the peritoneal cavity. The junction of the infundibulum with the ampulla, sometimes slightly constricted in young persons, is occasionally called the *neck.*

The uterine orifice is small, inextensible, and often stopped by a plug of mucus. It is practically impossible to catheterize it, and fluids injected into the cavity of the uterus do not readily pass through it. The abdominal orifice is larger and extensible. It is said to be closed in tubes cut from the living, but open after death. We may, with Waldeyer, consider the oviduct according to the directions which its different parts assume. A *horizontal* portion extends from the angle of the uterus outward and a little backward to the inferior pole of the ovary, an *ascending* portion, nearly at right angles to the preceding, which mounts vertically along the pelvic wall and the mesovarian margin as far as the superior pole, and a short *descending* portion which makes an acute angle with the latter, passing downward and inward, forming the so-called tubal loop, the infundibulum embracing the internal face and posterior border of the ovary (Fig. 2716). These portions are, however, by no means of fixed dimensions, as they depend largely upon the position of the uterus and upon the various influences that may displace the ovary and the folds of the broad ligament. The oviduct, with its attached peritoneum

often so covers the internal face of the ovary that that organ is not perceived when the pelvic cavity is opened.

Dimensions.—The following table shows the principal measurements of the oviduct:

Average length	12 to 14 cm.
Minimum length	6 "
Maximum length	20 "
Length of interstitial portion	1 "
Length of isthmus	3 "
Length of ampulla	8 "
Length of infundibulum	2 "
Length of ovarian fimbria	2.5 to 3 "
Length of other fimbriæ	1 to 1.5 "
Caliber of uterine orifice	0.05 to 0.1"
Caliber of interstitial portion	0.05 "
Caliber of isthmus near uterus	0.3 "
Caliber of ampulla, maximum	0.8 "
Caliber of peritoneal orifice	0.2 to 0.3 "
Thickness of walls, average	0.2 to 0.3 "

At its uterine termination the tube so gradually expands into the cavity of the superior cornu that its exact point of termination is difficult to determine.

Attachments.—Continuous with the angle of the uterus at its inner extremity, the oviduct lies in the superior or free edge of the broad ligament, hereafter to be described, and is attached at its lateral end by one of the fimbria, longer than the others (ovarian fimbria, *fimbria ovarica*, Figs. 2706 and 2707), to the suspensory ligament of the ovary. The triangular fold of the broad ligament that encloses it is known as the *mesosalpinx* (Fig. 2706, *b*). At its extremities the duct shares the movements of the organs to which it is attached, while its intermediate portion may move independently, its freedom depending upon the length of the duct and the laxity of the mesosalpinx.

Interstitial Portion.—In nulliparæ the oviduct is clearly seen to be a contracted continuation of the superior cornu of the uterus, and the narrowest point is not at the uterine orifice, but a little beyond. In multiparæ, however, the orifice is the narrowest portion. While passing through the uterine wall the duct is slightly bent with downward concavity. A layer of connective tissue separates it from the uterine substance proper.

Isthmus.—This resembles the vas deferens in its cord-like, resistant character and cylindrical form. It lies in the para-uterine fossa of Waldeyer, the round ligament of the uterus being before and below, the ovarian ligament and tuboovarian artery behind.

Ampulla.—This portion, slightly flattened from before backward, has a thinner wall and softer consistence than the isthmus. It is slightly irregular in caliber, with flexuosities which are more marked in the young. Its loop runs in front of the ovarian vessels and its descending branch is close against the external iliac vein.

Infundibulum.—This funnel-like expansion (Fig. 2706, 6′) is cut into twelve to fifteen laciniate, fringe-like processes or fimbriæ, and is hence often called the *fimbriated extremity*. The French, carrying out the similarity of the duct to a trumpet, call it the *pavillon*, a name also applied to the flaring mouth or bell of a trumpet. The ancients compared its gnawed appearance to the premorse root of the *Scabiosa succisa*, popularly known as the "devil's bite," the legend being that the arch enemy, angered at the good done by the medicinal virtues of the root, attempted to destroy it by biting it off, but only succeeded in leaving a ragged edge showing the marks of his attack. It is from the resemblance of the infundibulum to this root, and not from any evil influence it was supposed to exert, that it was called the *morsus diaboli*. It has also been compared to the corolla of a flower with a double row of petals (Henle), to a crinoid or sea-lily (Nagle), and to a medusa head.

The single fimbriæ are lanceolate, ovate, or filiform, not infrequently with irregularly notched edges, so that there may arise fimbriæ of the second or third order. Sometimes they may be fenestrated or form a lattice-work. One of them, larger than the others, has already been referred to as the ovarian fimbria (Fig. 2606, 7). Attached to a groove in the suspensory ligament, it does not usually quite reach the ovary, and from its termination there may extend, along the suspensory ligament, supplementary fringes (tuboovarian fimbriæ). The primary fimbriæ are usually plicated, the folds corresponding to those of the mucous membrane of the interior of the tube. In consequence of this arrangement, the abdominal orifice of the tube is not usually visible, at least in nulliparæ. It can, however, always be displayed by parting the plications, and is large enough to admit a small probe.

It is by this orifice that the ova leave the abdominal cavity, and many attempts have been made to clearly explain how they come to enter it. It was formerly supposed that at the time of ovulation the infundibulum suffered a species of erection by vascular congestion, and that then it clasped itself firmly around the ovary and prevented the escape of the ovum into the peritoneal cavity. Injection of the vessels in the cadaver does not confirm this, and, as Henle says, it is difficult to see how the infundibulum can select the exact place upon the ovarian surface where a follicle is about to rupture, or how it can be depended upon to execute such an act in view of the pressure and movements of the intestines. Others have supposed that there must exist in the ducts, in the fimbriæ, or in the broad ligaments muscular fibers by which adaptation of the infundibulum to the surface of the ovary is effected. This, too, appears to be without foundation. Excitation of the muscular coat of the oviduct in living animals merely produces vermicular movements, the direction of the fibers of the muscular tissue of the broad ligament is such that they draw the ovaries together rather than bring the infundibulum to the ovary, and the existence in the fimbriæ of special fibers capable of clasping the ovary cannot be demonstrated.

Experiments upon animals have shown, however, that both ova and semen may pass from one side of the abdomen to the other, and that it does not necessarily follow that, because an ovum does not at once reach the infundibulum, it may not eventually do so. Its movement is doubtless directed by the ciliated epithelium that lines the interior of the infundibulum and the ovarian fimbria. Notwithstanding this there is unquestionably a great loss of ova owing to the lack of accurate adaptation between the mouth of the oviduct and the ovary.

Interior Configuration.—The interior of the oviduct is lined with mucous membrane continuous with that of the uterus, but destitute of the glands that are so prominent a feature of that organ. This membrane has a striking peculiarity in that it is arranged in numerous longitudinal folds that form an intricate series of narrow passages—the tubal labyrinth (Figs. 2717, 2718)—affording a free though retarded passage to fluids and minute bodies that pass from the abdominal cavity to the uterus. These folds appear in the interstitial portion as two or three small crests which are, in the isthmus, prolonged and multiplied as *principal* folds, which, however, disappear on distention of the tube, and attain their greatest development in the ampulla, where they no longer disappear on distention and vary greatly in size, some passing across the lumen of the tube to the opposite side and developing on their faces secondary and tertiary folds, so that a cross-section of them resembles the arbor vitæ of the cerebellum. These folds are continued, much reduced in size, upon the infundibulum.

The arrangement seems admirably adapted for retarding the movements of the ovum and the spermatozoa, which probably meet each other at this point. It indeed seems likely that the ampulla is a *recep-*

taculum seminis, and that it becomes, after repeated copulations, charged with spermatozoa, which may remain there in an active state for several days, so that when a matured ovum once enters, its fecundation is practically assured.

Fig. 2717.—Cross-section of the Oviduct near the Uterine Orifice. (Orthmann.)

Investigations on animals show that the ovum is from three to eight days in passing through the oviduct. Hyrtl found a human ovum in the uterine end of the duct four days after menstruation. The period of eight days cannot be much exceeded in the human species, as the ovum attains in the second week a diameter of three to six millimeters which is greater than that of the uterine orifice of the tube.

On the other hand, the progress upward of the spermatozoa is comparatively rapid. Having a flagellate movement of their own, they are able to travel without the assistance of the female organs. In guinea-pigs they have been known to reach the middle of the oviduct within fifteen minutes after copulation, and from what is known of their rapidity of progress in other situations, it seems probable that in the human species they require about two hours for a similar migration.

Structure.—The oviduct is a muscular tube outwardly invested with a serous layer derived from the peritoneum, inwardly lined with a mucous membrane. The serous coating forms a complete investment, the vessels entering along its inferior border through the folds of the mesosalpinx. It is continuous medially with the serous investment of the uterus, and laterally is continued over the external surface of the fimbriæ. A loose, subserous, connective tissue unites it to the muscular coat.

The muscular tunic is composed of smooth fibers arranged in two layers, an inner one of circular fibers and an outer one in which the fibers are arranged longitudinally. The circular layer is a continuation of the similar fibers of the uterus, is thicker at the uterine extremity, andat the infundibulum forms a sphincter-like ring. The longitudinal fibers are continuous with the transverse fibers of the uterus and are continued as a very thin sheet upon the infundibulum, one fascicle extending upon the fimbria ovarica and constituting what is sometimes called the *musculus attrahens tubæ*.

The mucous membrane is composed of a layer of ciliated epithelium seated upon a submucous connective tissue containing some round cells resembling those of the uterus, and which are believed to assist in forming a decidua in the case of tubal pregnancy. It possesses no glands. The epithelium increases somewhat in thickness toward the abdominal orifice. The direction of the ciliary wave is toward the uterus, and experimental injections of minute bodies into the abdominal cavity show that it is an efficient cause of the progression of the ovum through the duct. The epithelium lines the interior of the infundibulum and becomes continuous at the edge of the fimbriæ with the peritoneum. Upon the ovarian fimbria or along the suspensory ligament it is continued as far as the ovary, becoming continuous there with the cubical epithelium of that organ.

Arteries.—From the anastomotic loop formed by the ovarian and uterine arteries three branches are given off for the supply of the oviduct. These are, respectively, the *lateral tubal*, derived from the ovarian, which passes in front of the fimbria ovarica and ascends along it, supplying it and sending a branch to each of the other fimbriæ, and ending by anastomosing with the middle or internal tubal; the *medial tubal*, derived from the uterine, supplying the interstitial portion and isthmus of the oviduct, and curving outward to form by anastomosis with the external tubal the infratubal arch; and the *middle tubal*, usually given off from the uterine a little farther out. It passes in front of the ovary and divides into two branches, which anastomose with the external and internal tubal, forming a second infratubal arch.

Veins.—These also form a vascular arcade with more frequent anastomoses. They discharge into the uterine and ovarian veins. One branch runs along the round ligament of the uterus and communicates with the epigastric vein.

Lymphatics.—These take origin from the mucous membrane,from a subperitoneal network, and discharge into two or three trunks which extend along the oviduct, unite with others coming from the uterus, and ascend along the suspensory ligament to the lumbar glands.

Fig. 2718.—Cross-section of the Oviduct near the Abdominal Orifice. The folds of the mucous membrane are very numerous and complicated, forming the tubal labyrinth; the muscular coat is very thin but rich in vessels. (Orthmann.)

Nerves.—These are derived from the ovarian plexus and are closely connected with the uterine nerves. They unite under the peritoneum to form what is called by Jaques the *fundamental* plexus, from which finer fibers penetrate between the muscular layers,

forming a second or intramuscular plexus which supplies the muscle fibers; from this again fibers are distributed to the epithelium.

The Uterus.—*Etymology.*—From the Latin *uterus*, the womb, probably connected with *uter*, a skin bottle or bag. The later Latin appellation, *matrix*, is also sometimes used. This originally meant a breeding animal. Greek, *μήτρα*, *ὑστέρα* (the last, the uterus being the last organ that presents in the pelvis), whence come many modern derivatives, such as

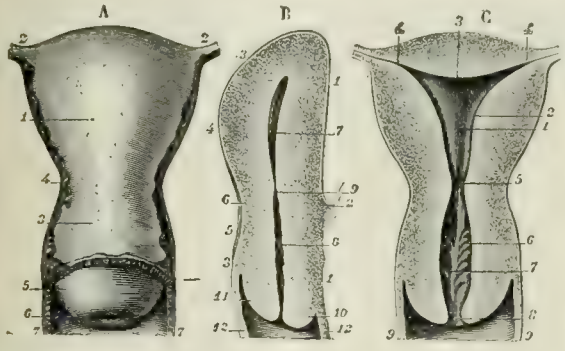

Fig. 2719.—Virgin Uterus of Twenty-two Years. (Sappey.) *A*, *Anterior face*—1, Body; 2, 2, superior angles; 3, cervix; 4, isthmus; 5, intravaginal portion of cervix; 6, its external orifice; 7, vagina. *B*, *Median section*—1, 1, Profile of anterior face; 2, vesicouterine cul-de-sac of peritoneum dividing this face into two nearly equal parts; 3, 3, profile of posterior face; 4, body; 5, cervix; 6, isthmus; 7, cavity of body; 8, cervical canal; 9, internal orifice; 10, anterior lip of the os uteri; 11, posterior lip; 12, 12, vagina. *C*, *Frontal section*—1, Cavity of body; 2, its left lateral border; 3, its superior border; 4, 4, its lateral angles; 5, its inferior angle forming the internal orifice; 6, cervical canal; 7, arbor vitæ of its posterior wall; 8, its lower extremity; 9, vagina.

metralgia, metritis, metrorrhagia, hysteria, hysterectomy, etc. Another Greek appellation, used by Hippocrates, was *δελφύς*, whence are derived several terms used in zoological classification, such as Monodelphia, Didelphia, Ornithodelphia. French, *uterus, matrice;* Italian, *utero, genitura;* German, *Gebärmutter, Mutter, Fruchthälter.* The Talmudists called the uterus "the sleeping chamber," of which the cervix was "the porch."

History.—It was probably known to the ancients from an early period, though it would seem that at first no very clear distinction was made between it and the vagina. The Greek physicians supposed it to be movable, ascending upward toward the diaphragm when excited and thus producing a variety of disorders. Plato calls it a wild beast which never follows reason, and which, through non-satisfaction of its desires, roams about in the body and also excites inordinate lust. That this view existed also among the Hebrews may perhaps be inferred from Prov. xxx. 15, 16. Soranus first showed that its attachments were such that this movement was impossible, yet the error did not disappear from medical science until the practice of dissection became general. Galen, considering that the female should possess all the organs of the male, supposed it to be the homologue of the penis, withdrawn from sight in accordance with the colder nature of the sex. The muscular character of the uterus was first demonstrated by Arantius (1530–89).

Definition.—A single, hollow, median, and symmetrical structure, peculiar to mammals, situated in the cavity of the pelvis between the rectum and the urinary bladder. It is formed by the thickened confluence of the Müllerian ducts, and serves as the organ of gestation and parturition. It receives the impregnated ovum, maintains it during embryonic and fetal development, and expels the fetus at maturity.

The function of child-bearing, which appears to be the most important one of the female economy, has a remarkable effect upon the organ that contains and nourishes the developing embryo, affecting profoundly its size and its anatomical organization. This organ is also subject to a series of rhythmic changes, habits impressed upon it as a periodical preparation for gestation and known as menstruation. The function of gestation, and in a minor degree that of menstruation, entail anatomical variations greater than are found in any other organ of the body.

Form.—The nulliparous uterus (Fig. 2719) has the shape of an inverted flask, flattened and slightly bent, from behind forward. The older anatomists compared it to a *cucurbitula* or cupping glass, so called because of resemblance in shape to a small gourd or cucumber. Indeed, the shape of the uterus is quite accurately represented by that of a short cucumber, slightly larger at one end than at the other, and bent near the smaller end.

Divisions.—Its expanded upper portion is the *body* or *corpus*, its narrower, lower part the *neck* or *cervix*, while the slight constriction between these is the *isthmus.* From either side of the organ, at its upper part, are given off the so-called *anneæ:* the oviduct, the round and ovarian ligaments, which latter connect with the ovaries (see Fig. 2706). The part of the uterine body above the plane passing horizontally through the insertions of the annexa is termed the *fundus*, and the part below that plane is sometimes distinguished as the body proper (*corpus proprium*).

The lower part of the neck is embraced by the vagina, like a sleeve, the line of adherence running obliquely and extending farther down in front than behind (Fig. 2720). The cervix is thus divided into a *supravaginal* and a *vaginal* portion. To the palpating finger the vaginal portion feels like a hard, smooth projection with a central depression or slit, the *orificium externum*, or external orifice of the cavity of the uterus. Its peculiar shape and consistence led Lieutaud to call it the *museau de tanche*, the tench's muzzle, or, in Latin, *os tincæ*, which has become by usage *os uteri* or *os uteri externum*, the

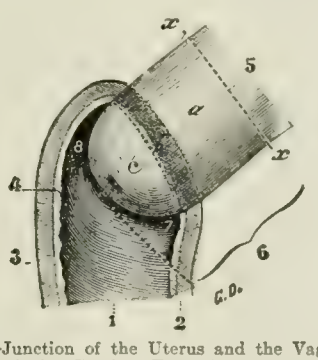

Fig. 2720.—Junction of the Uterus and the Vagina, showing the Segments of the Cervix, (Testut.) 1, Vagina, with 2, its anterior wall; 3, its posterior wall; 4, its mucous membrane; 5, body of the uterus; 6, cervix of uterus, with *a*, its extravaginal portion; *b*, its vaginal portion; *c*, its intravaginal portion or os uteri; 7, anterior cul-de-sac; 8, posterior cul-de-sac: *x*, *x*, separates the body and the neck of the uterus.

mouth of the uterus. It will be perceived that this term applies to the entire vaginal portion of the cervix rather than to the orifice itself. This orifice is rounded in nulliparæ, and in those who have borne children is a short, transverse slit, often with somewhat irregular edges, the *lips* or *labia* (Fig. 2721). The anterior lip is the thicker and the lower. Both lips are in contact with the walls of the undistended vagina (Fig. 2722).

From the sides of the uterus its peritoneal investment is continued laterally in the form of the broad ligament, between whose layers are the vessels and

nerves for the supply of the organ, which thus penetrate at what may be called its lateral edges.

The body comprises about two-thirds of the entire organ. Its upper end, the fundus, is free and covered by closely adherent peritoneum. It is smooth and glistening, and the superincumbent coils of intestine

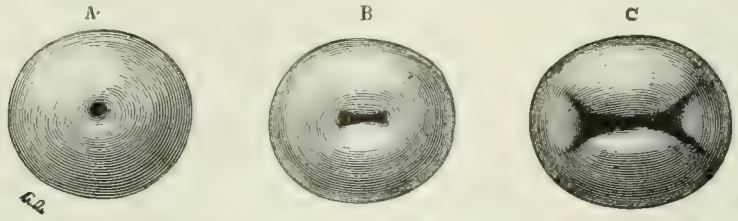

Fig. 2721.—The External Orifice of the Uterus. (Testut.) *A*, In the virgin; *B*, in a primipara, *C*, in a multipara

glide over it with a minimum of friction. In nulliparæ it has but little convexity, but after repeated pregnancies it becomes markedly rounded both anteroposteriorly and from side to side (Fig. 2723). By its continuity on either side with the oviducts are formed the *angles* of the uterus. In most lower animals these angles are much more marked, owing to a less complete fusion of the Müllerian ducts. In the human species also a bicornuate uterus is occasionally seen. The posterior surface of the body, rounded and smooth, can be seen from above when the pelvic cavity is opened and the intestines are removed; the anterior surface, however, is not visible, it being in contact with the bladder, which imparts to it a slight flattening.

The cervix is of a nearly cylindrical form, slightly enlarged at the middle in nulliparæ, much less or not at all in those who have had repeated pregnancies.

Fig. 2722.—Section through the Middle of the Uterus and Upper Part of Vagina. (Henle.)

The vaginal (intravaginal) portion of the cervix is a rounded projection, having under physiological conditions a rosy color and a firm consistence. Its base is circular in virgins, slightly elliptical in those who have borne children (Fig. 2721). The external orifice varies much in shape and in the appearance of its lips. Rounded in the virgin, it becomes a slit in the primipara, and after repeated pregnancies is gaping, irregular, and puckered, the lips often presenting scars or fissures. In these cases the cervix undergoes considerable absorption.

Cavity.—The walls of the uterus are from 10 to 15 mm. thick in nulliparæ (Fig. 2719, *B*, *C*), somewhat greater in multiparæ (Fig. 2723, *B*), diminished a little at the neck and at the orifices of the oviducts. This thickness nearly obliterates the lumen, but there is a virtual cavity divisible into two parts: an upper, triangular, transversely placed cleft, the *cavum uteri*, belonging to the body of the uterus; and a lower, fusiform portion, the *cervical canal* (*canalis cervicis*) belonging to the neck. A contracted pass, the *internal orifice* (*os uteri internum*), unites the two.

The shape of the cavum uteri is triangular, or, more accurately, it is formed by three slender triangles united by their bases; the two upper ones, the cornua, leading to the orifices of the oviducts, the third leading downward to the internal orifice. In multiparæ this shape is somewhat modified, the cornua enlarging at the expense of the lower triangle. Traces of the primitive union of the Müllerian ducts can usually be found in young persons, either as a marked raphe or as a triangular depression, on the anterior and posterior walls. Sometimes the entire cavity is divided and the uterus thus becomes bilocular like that of rodents. Among the older, fanciful views with reference to generation, was one that male children were developed on the right side of the uterus, females on the left, the male seeking the warmth of the liver (Galen). It has been suggested that the rare cases of superfetation that have been noted can be explained by an anomalous, bilocular condition of the uterus.

The internal orifice, often called the internal os, is really a passage four or five millimeters in length, corresponding to the isthmus of the uterus. It frequently is smaller than the external orifice, and offers more resistance to the probe. The columns of the next section are prolonged into it.

The cervical canal expands somewhat on passing from either end toward the middle. The mucous membrane of its anterior and posterior surfaces presents a series of remarkable folds, constituting the *arborœ vit uterinœ* of the older anatomists (Fig. 2724). Running axially along each wall is a slightly elevated ridge or *column*, from which arises a series of penniform folds, the *plicæ palmatœ*, which may divide and subdivide, the whole presenting an appearance somewhat like the ribs of a leaf. The folds are so arranged that those on opposite sides of the neck fit into each other.

The capacity of the cavity of the unimpregnated nulliparous uterus is but slight, the walls being for the most part everywhere in contact or separated by a thin layer of mucus. It is estimated at from 2 to 5 c.c., or fl. ℥ ss. to fl. ℥ 1¼. In multiparæ it increases to from 5 to 8 c.c., or fl. ℥ 1⅛ to 2⅛ (Guyon).

Dimensions.—The following table represents averages from measurements made by Rieffel, Waldeyer, and others.

	Nulliparæ. Millimeters.	Multiparæ. Millimeters.
Total length	60	70
Length of body	35	45
Length of neck	25	25
Length of vaginal portion of neck	10	10
Breadth between insertions of oviducts	40	45
Breadth at isthmus	20	30
Breadth at middle of cervix	25	30
Thickness (anteroposterior diameter) of body	20	30
Thickness (anteroposterior diameter) of neck	20	25
Total length of cavity	55	60–65
Length of cavity of body	25	31–40
Length of cavity of isthmus	5	3–5
Length of cavity of neck	25	20–24
Breadth of cavity between oviducts	24	30–35
Breadth of cavity at isthmus	4	
Breadth of cavity at middle of cervix	8	9
Depth (anteroposterior diameter) of cavity	¾	12
Thickness of walls of body	10–15	20
Thickness of walls of neck	8–10	15

	Millimeters.
Total length of uterus of child	25–35
Total length of senile and atrophied uterus	30
Pregnant uterus in the last month:	
Greatest length	360
Breadth of body	250
Thickness of body	240
Length of cervix	45–50

As a general, rough estimation it may be said that the adult, nulliparous uterus is three inches long by two inches wide and one inch thick.

Weight.—According to Rieffel the weight of the nulliparous uterus averages forty grams, ranging from thirty-two to fifty. The weight of the multiparous uterus is considerably greater, averaging fifty-five

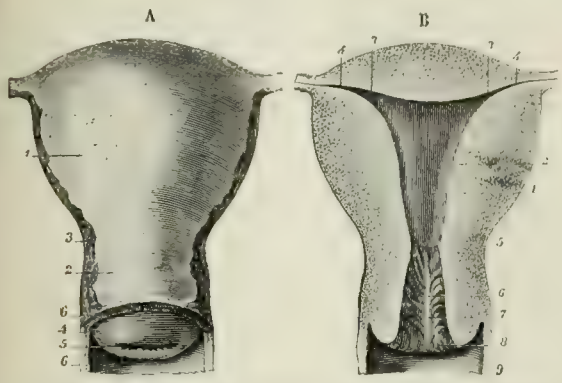

Fig. 2723.—Multiparous Uterus of Twenty-six Years. (Sappey.) *A. Anterior face*—1, Body, much longer than cervix; 2, cervix, shorter than body; 3, isthmus; 4, os uteri; 5, external orifice, having the figure of a transverse slit; 6, 6, upper end of vagina continuous with the neck at the base of the os uteri. *B. The uterine cavity*—1, Cavity of the body; 2, its left lateral border; 3, 3, its superior border or base; 4, 4, its superior angles, continuous with the oviducts; 5, its inferior angle, forming the internal orifice; 6, cervical canal; 7, arbor vitæ of its posterior wall; 8, posterior lip of the os uteri externum; 9, upper end of the vagina.

grams and varying from forty-eight to seventy. Waldeyer reports the weight of the uterus during the last month of pregnancy as from 900 to 1,200 grams. Roughly speaking, it may be said that the weight of the uterus varies from one ounce avoirdupois in the unimpregnated female to two pounds in the parturient one. The specific gravity of the uterine substance is 1.052.

Consistence.—During life the uterus is soft, depressible, and flexible, especially at the isthmus. This is

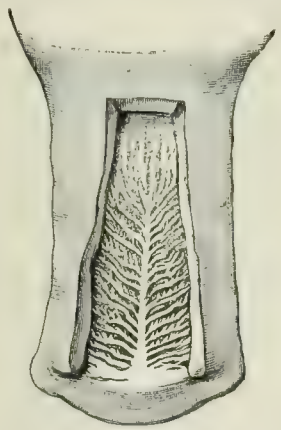

Fig. 2724.—The *Arbor Vitæ* or *Plicæ Palmatæ* of the Wall of the Cervical Canal shown by Cutting a Section from the Wall. (Nagel.)

more marked in nulliparæ. After death, from cadaveric rigidity and the emptying of the vessels, it becomes more firm and unyielding.

Position.—The uterus not being rigidly bound, is subject to a wide range of variations in position, many of which are compatible with health. Thus it may, as a whole, be turned forward, backward, or sideways (anteversion, retroversion, lateroversion); it may, as a whole, be displaced in the horizontal plane (anteposition, retroposition, lateroposition); it may be raised or lowered (elevation, depression); it may be bent upon itself (anteflexion, retroflexion, lateroflexion) the bending usually occurring at the isthmus; or it may be twisted upon its own axis (torsion). Several of these displacements are often combined. It is not surprising, therefore, that there should have been

Fig. 2725.—Normal Position of the Uterus in the Virgin. (Schultze.)

Fig. 2726.—Normal Position of the Uterus in a Multipara. (Schultze.)

much discussion as to the normal position of the organ. Nagel, Waldeyer, Rieffel, and most recent writers hold that the *typical* position of the uterus, as derived from a study of its embryonic development and general tendencies, is as follows:

In the healthy and normal adult female, standing in the erect position, with rectum and bladder approximately empty, the uterus is anteverted and anteflexed (Figs. 2708, 2725, 2726). The axis of the cervical canal corresponds nearly to the axis of the pelvis, the external orifice being at the height of the top of the symphysis pubis. The axis of the body is nearly horizontal, the fundus does not reach the plane of the superior strait, and is some distance behind the symphysis.

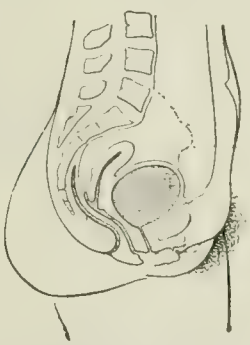

Fig. 2727.—Situation of the Uterus during Repletion of the Bladder. (Schultze.)

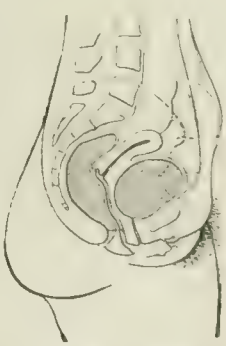

Fig. 2728.—Situation of the Uterus during Repletion of the Bladder and Rectum. (Schultze.)

This typical position may be altered by a variety of causes and thus a number of secondary positions be produced, all of which may be normal in the sense that they in no way interfere with the functions of the uterus nor with those of the surrounding organs. Thus it may be pushed backward by a distention of the bladder (Fig. 2727), or forward by a distention of the rectum, or considerably elevated by a distention of both at the same time (Fig. 2728). The posture

of the subject, acting upon the abdominal contents as well as upon the uterus, has some effect. Thus the knee-elbow position of gynecologists throws the viscera toward the diaphragm and causes the fundus of the uterus to be directed more toward the umbilicus. The expulsive action of the muscles of the abdominal wall, by pushing downward the intestines, affects the anteflexion and anteversion, and at the same time depresses the organ. Even the action of respiration has a slight effect. The state of tonicity of the pelvic floor and the vaginal walls and the repletion of the vessels have also considerable influence.

Fixation.—The position of the uterus is maintained by the following connections: (1) with the vagina and bladder; (2) with the pelvic fascia by means of the parametrium and its vessels; (3) with the pelvic peritoneum by the broad ligament; (4) by special bands known as the round and uterosacral ligaments.

The attachment of the vagina (Fig. 2720) is along a one from six to eight millimeters in breadth, and is very intimate, the muscular and connective tissue and the mucous membrane of the two organs being continuous, as might be expected, considering that both were originally developed from the same tubular structure.

The neck of the uterus is attached to the fundus of the bladder by loose connective tissue containing numerous veins. The vesicouterine fold of the peritoneum closes the connection above. This usually descends only as far as the isthmus of the uterus (Fig. 2719, *B*, 2), but in multiparæ is occasionally seen to reach the vagina, in which case the uterus has no immediate union with the bladder.

front a uteropubic sheet passes to the bladder and thence to the pubis. Some thickened bands of this have been called the vesicouterine ligaments. Laterally, through the base of the broad ligament, along the vessels and nerves that enter here and themselves constitute an elastic band, can be traced sustaining bands that have been called by Kocks the cardinal ligaments. It will be seen that the neck of the uterus is thus suspended hammock-wise in a network of connective-tissue cordage.

The broad ligaments (*ligamenta lata uteri*, Figs. 2706, 2730, 2731) are formed by reflections of the pelvic peritoneum upon the uterus and the annexa. Together they constitute a common mesentery for these organs. When spread out each has the appearance and shape of a membranous wing, which led De Graaf to style it the *ala vespertilionis*, or bat's wing; and the French anatomists still use the term *ailerons*, or little wings, for its subordinate divisions (Fig. 2706, *a*, *b*, *c*). The external insertion or hilum—that is to say, the line where the ligament is reflected upon the lateral wall of the pelvis—is about two centimeters behind the transverse diameter of the superior strait, a little in front of the hypogastric artery. It passes up over the psoas and the external iliac vessels, surrounding the suspensory ligament of the ovary and the ovarian vessels and nerves, where it is lost. Waldeyer has given to this upwardly extending process the name of *mesodesma suspensorium*. Its inferior or basal insertion is broad and situated on the pelvic floor nearly in the biischiatic line (Fig. 2730). Its upper edge contains the oviduct, and, beyond the

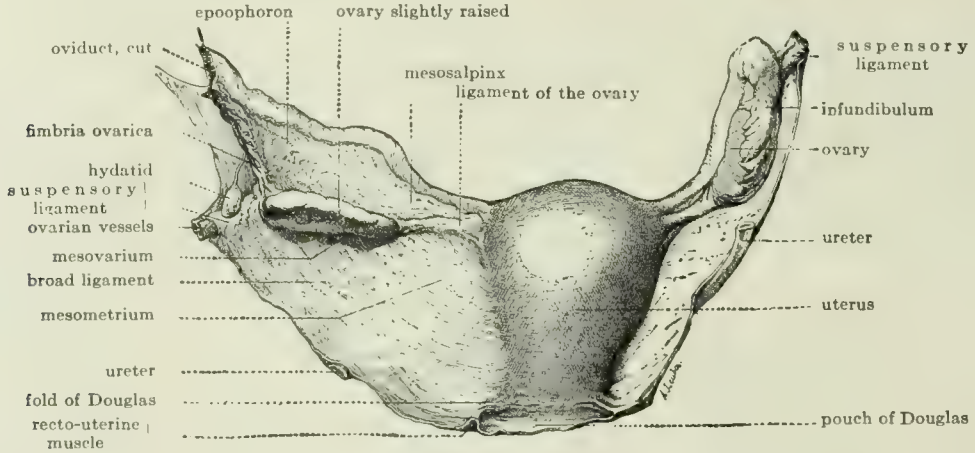

Fig. 2729.—The Uterus, Oviducts, and Ovaries, seen from Behind. (Spalteholz.)

The pelvic fascia, or sheet of connective tissue that lines the pelvic cavity, has necessarily important relations with the uterus, since that organ is itself a portion of the pelvic floor. This fascia varies greatly in its consistency, in some situations being loose and offering but little resistance; in others being condensed into bands and sheets that fix and restrain the organs with which it is united. It is particularly associated with the great vascular trunks, and often contains in its meshes masses of fat. Virchow proposed the name *parametrium* for the extensions of this fascia that invest and are immediately adjacent to the uterus. They reach the viscus by the base of the broad ligament, along the branches of the uterine artery, and cover its lateral edges and the supravaginal portion of the cervix, extending upward a varying distance under the peritoneal covering and gradually disappearing as they reach the upper part of the body.

Behind, a uterosacral sheet can be traced along the sides of the rectum to the sacrum and the coccyx; in ovary, is continued upon the suspensory ligament. From its anterior surface is raised a small fold containing the round ligament (*mesodesma teres* of Waldeyer), while from its posterior surface the ovarian ligament and the ovary itself are suspended by the *mesovarium*. The portion above this fold is thin, contains the remains of the Wolffian body and its ducts with but little connective tissue, and is known as the *mesosalpinx;* that below its thicker, and, since it affords the special investment of the uterus, is called the *mesometrium*. There is here found a considerable amount of loose connective tissue (parametrium), the uterine vessels and nerves and the ureter, besides a thin layer of smooth muscular fibers continuous with the muscular tissue of the uterus.

The anteflexed position of the uterus bends forward the two ligaments so that they form a shelf that supports the intestines (Fig. 2729), and which, while almost vertical at the sides, is nearly horizontal in the middle. It divides the pelvis into two cavities or

pockets, a rectouterine behind and a vesicouterine in front.

The portion of the mesometrium that immediately invests the uterus is called the *perimetrium*. Behind, it is continuous with the peritoneal covering of the rectum; in front, with that of the bladder. In the latter situation it reaches the uterus about at the isthmus, forming the *uterovesical fold*, and is then reflected over the anterior surface of the body, the fundus, the posterior surface of the body, and the supravaginal surface of the neck, passing thence to the upper part of the vagina and then being reflected upon the rectum, forming the *rectovaginal fold* (fold of Douglas, Fig. 2729). This fold is interrupted laterally by two bundles of smooth muscular fibers which pass from the uterus along the sides of the rectum to the sacrum. These, the *uterosacral ligaments*, do not reach as low as the bottom of the fold, and there is consequently formed between them a well-marked pocket, lying between the uterus in front and the rectum behind, which is known as the *rectovaginal* pouch or pouch of Douglas (*excavatio rectouterina*), from James Douglas, professor of anatomy and surgery in London (1642–1675). This pouch is the lowest portion of the abdominal cavity, and any effusions are likely to collect there. It can easily be palpated through the vagina.

It has already been mentioned that the ovarian and round ligaments represent portions of the genitoinguinal ligament or gubernaculum of the genital gland, which, instead of remaining free throughout its course, has become attached to the uterus—that is to say, to the enlarged Müllerian duct (Fig. 2701). Accordingly the ovarian ligament is inserted upon the uterus behind the superior cornu, while the round ligament arises from in front of the same, a little below the insertion of the oviduct. The round ligament then passes down between the layers of the mesometrium and the parametrium, above the ureter, the uterine, the vesicovaginal, the obturator, and the external iliac vessels to the internal abdominal ring, lifting up the peritoneum as it passes to form a slight investment (*mesodesma teres*, Waldeyer). It then passes through the inguinal canal, sometimes surrounded by a peritoneal diverticulum, called the canal of Nuck (Anton Nuck, professor at Leyden, 1650–92) and having about the same relations as the spermatic cord of the male. Finally its fibers separate to be inserted in the subcutaneous tissues of the labium majus. The round ligaments deserve that appellation only in the middle of their course; in their upper part they are flattened, below expanded in a fan-like manner. They are twelve to fifteen centimeters in length, about three to five centimeters broad, and are composed mostly of muscular tissue, having, therefore, no great tensile strength. During pregnancy they increase to four times their normal size.

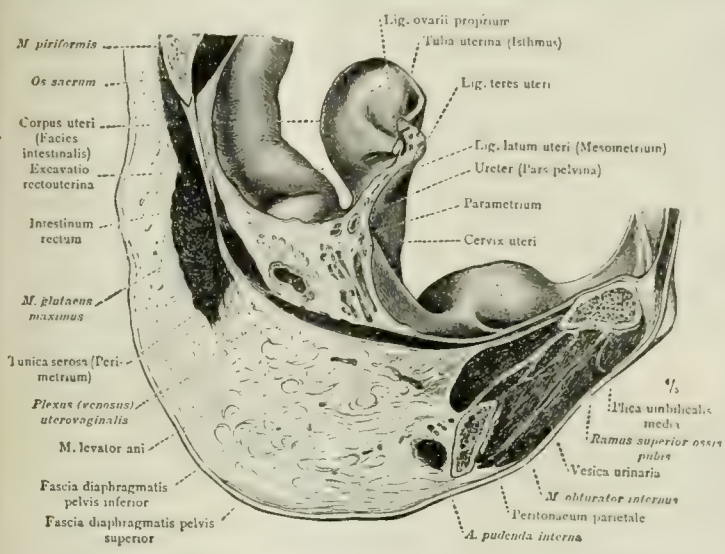

FIG. 2730.—Anteroposterior Section through the Female Pelvis Four Centimeters to the Right of the Median Line. (Toldt.) The section cuts the broad ligament and shows the continuity of its two peritoneal layers with the parietal peritoneum of the pelvic floor. It also shows the parametrium, the pelvic diaphragm, and, under it, the fatty tissue of the ischiorectal fossa. The uterus is shown more erect than normal. Made from a frozen preparation.

The uterosacral ligaments have already been mentioned. They are fibromuscular bundles that pass, from just below the isthmus of the uterus, backward along the sides of the rectum to the sacrum. Occasionally secondary *uterolumbar* bands are seen that are inserted on the last lumbar vertebra.

Relations.—The anteroinferior surface of the body is often called the vesical surface because of its contact with the bladder. It appears normally to remain in contact with that organ, lying upon it as upon a water-bed and adapting itself to its states of repletion and depletion. Coils of intestines rarely insinuate themselves between these organs. The superoposterior surface is called the intestinal surface because it is covered with coils of the small intestine or of the pelvic colon. These never descend, however, into the pouch of Douglas.

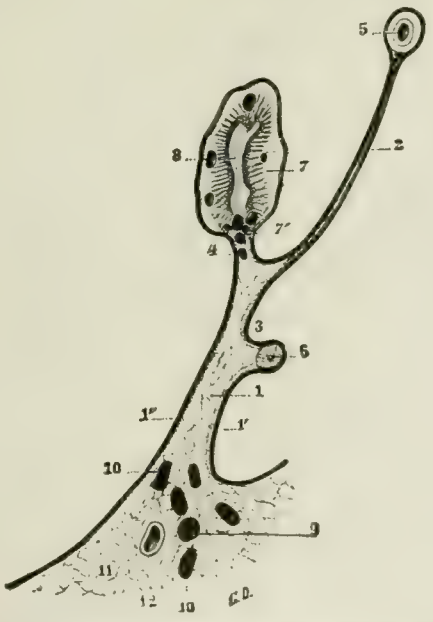

FIG. 2731.—Sagittal Section of the Broad Ligament right side, inner surface of section). (Testut.) 1, Broad ligament, with 1′, its anterior layer; 1″, its posterior layer; 2, mesosalpinx; 3, mesodesma teres; 4, mesovarium; 5, oviduct; 6, round ligament; 7, ovary, with 7′, its hilum and vessels; 8, ovisacs; 9, uterine artery; 10, uterine veins; 11, areolar tissue of pelvis; 12, ureter.

The principal relations of the neck of the uterus are with the ureter and the uterine artery. The ureter,

passing down obliquely through the base of the broad ligament, crosses the external border of the neck a little below its internal orifice, passes along the cervical attachment of the vagina for about one centimeter, and reaches the anterior wall of the vagina at about the level of the external orifice of the cervix. It is here surrounded by loose connective tissue and by veins. In this course the ureter may lie immediately against the cervix and is rarely more than two centimeters from it. The uterine artery crosses the ureter at about the level of the vaginal portion of the cervix and at an average distance of two centimeters from its border.

The relations of the uterus to the skeletal framework have already been mentioned. From Fig. 2732 it will be seen that the external orifice of the cervix is situ-

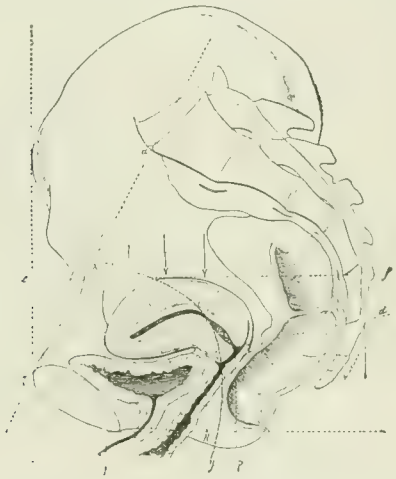

Fig. 2732.—Scheme showing the Relations of the Uterus to the Skeleton. (Rieffel.) *x*, *y*, Axis of pelvic cavity; *a*, *b*, plane of superior strait; *c*, *d*, line from superior fourth of symphysis to sacrococcygeal articulation; *e*, *f*, horizontal through union of fourth and fifth sacral vertebræ; *M*, vertical through fundus; *N*, vertical through internal orifice; *P*, vertical through external orifice.

ated near the point where a line drawn from the upper fourth of the symphysis pubis to the sacrococcygeal articulation intersects the axis of the pelvic cavity. It is really slightly behind this point and therefore a little nearer the posterior wall of the true pelvis. According to Waldeyer it is in the frontal plane passing through the two spines of the ischium. In the figure it is shown slightly forward of this plane. The fundus is about twenty to twenty-five millimeters behind the symphysis pubis. The lowest point of the uterus—that is to say, the anterior lip of the os—is on a level with the superior third of the symphysis and the last coccygeal vertebra. The highest part of the uterus in its typical position is not the fundus but the posterior surface of the body. It corresponds to a horizontal plane carried through the fourth sacral vertebra (Waldeyer) or a little below (Rieffel). A vertical through the internal orifice of the cervix passes a little behind the middle of the perineum. Another through the external orifice passes through the posterior fourth of the perineum. According to Waldeyer, a vertical passing through the anterior part of the fundus reaches the middle of the urethrovaginal septum. In the figure it is thrown a little forward of that. As the uterus is subject to considerable changes of position, these data can only be approximate.

Structure.—The walls of the uterus are formed of a serous coating derived from the peritoneum—the *perimetrium;* a subserous layer of loose connective tissue—the *parametrium;* a thick mass of unstriped muscular fibers—the *myometrium;* and the mucous membrane or *endometrium* that lines the interior. These distinctions are of especial value in studying the pathological conditions of the organ.

The peritoneal investment has already been considered. Its attachments to the subjacent layer, or parametrium, are of considerable importance. Where the latter tissue is abundant, as upon the posterior portion of the cervix, the peritoneum can be readily lifted into folds or stripped off by the finger or the handle of the scalpel. Where entirely wanting, as on the fundus and the greater portion of the body, the peritoneum cannot be readily removed from the subjacent muscular layer. Between these areas there is an intermediate zone both on the anterior and on the posterior surfaces of the uterus, in which the parametrium is scanty, but still in sufficient quantity to permit one to dissect off the serous layer. These zones are crescentic in form, the points of the crescent being at the insertion of the round ligament in front and the ovarian ligament behind. The posterior crescent extends rather farther downward than does the anterior one. The application of these facts to operative surgery is obvious.

The *myometrium* or muscular tissue of the uterus constitutes almost its entire mass. Indeed it may be said that the whole organ is one dense, closely knit muscle, composed of fibers interwoven with each other in every direction, interspersed with bundles of white fibrous and yellow elastic connective tissue. The elastic fibers are especially numerous near the external orifice, and are believed to be of advantage in the expansion of the os that occurs during labor.

While it is not possible to make an accurate separation of the muscular tissue into sheets distinguished by the direction of the fibers, as is done in other hollow viscera, it is convenient and customary to speak of three layers. Of these the middle one is the most important, as it is distinguished by the presence of large venous trunks, the uterine sinuses, which have given it the name of the *vascular layer.* The muscle bundles surround the vessels in every direction, so that, when they contract, the blood is practically squeezed out, thus affording an important means of stopping hemorrhage after labor. This arrangement is particularly noticeable in the fundus, the usual seat of the placenta, and is not found upon the cervix.

The external layer is also composed of fibers having every direction; it is not, however, so rich in vessels. It is extended outward beyond the uterus proper upon the attachments of the organ: the broad, round, ovarian, and uterosacral ligaments, the oviducts, the vagina, the bladder, and the rectum. The internal layer is thin and formed of a network of longitudinal, oblique, and circular fibers, the latter forming sphincter-like rings around the entrance of the oviducts. At the internal orifice of the cervix they form an annular bundle sometimes called the cervical sphincter.

The *endometrium,* or mucous lining, has, in the healthy uterus, a grayish-pink appearance, is soft, and easily torn. At the oviducts and vagina it is continuous with the mucous membrane lining those organs. It is composed throughout of a ciliated epithelium which is well developed only during the period of sexual activity, the direction of the ciliary wave being toward the external orifice. The epithelium is seated upon a membrana propria, but without any submucosa, a matter which should be remembered in the curetting of the uterus, as the instrument readily passes through into the muscular layers and may produce extensive lacerations and even perforation.

Some differences occur between the lining of the body and that of the cervix. In the body the epithelium is cylindrical, its nuclei being placed at about the middle of the cell; the protoplasm is easily stainable. The membrana propria is a network of connective-tissue fibers with stellate cells, and in its meshes are found cells having the character of leucocytes, so that

the tissue appears to have a lymphoid character. On the surface of the membrane are seen, spaced at distances of about 0.1–0.2 millimeter., the openings of tubular glands, resembling in form the glands of Lieberkühn of the small intestine. These are usually simple but sometimes branched. They are lined with ciliated epithelium, the direction of the ciliary wave being from the fundus toward the mouth of the gland. Their secretion is not, in a healthy state, very abundant, as the surface is merely moistened with mucus which has an alkaline reaction.

In the cervix the epithelial cells are longer, thinner, and narrowed at the base; their nuclei are either in several rows or situated nearer the base, and the protoplasm is not readily stained. The glands here are more utricular in character and incline to be

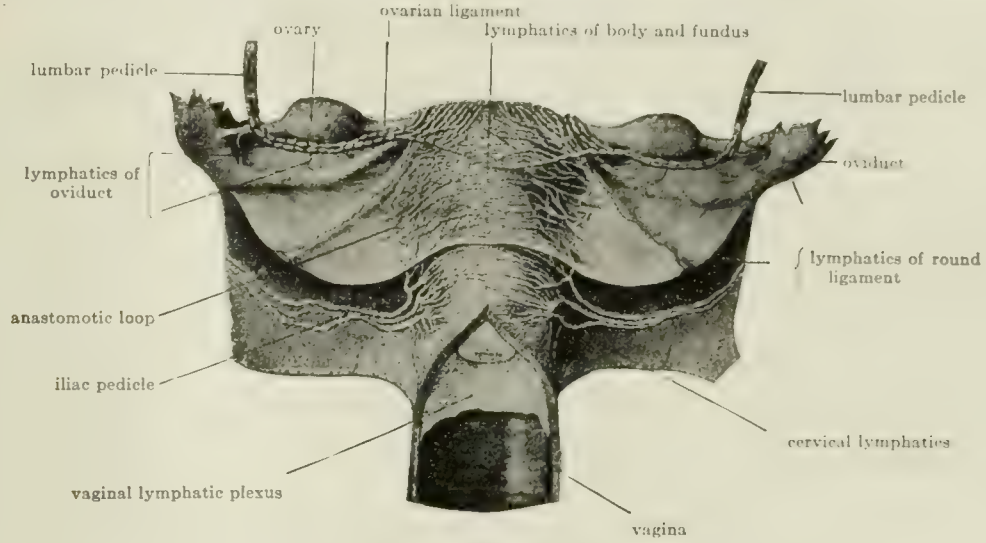

Fig. 2733.—Lymphatic Vessels of the Uterus. (Poirier.)

branched. They secrete an extremely viscid mucus, difficult to remove, which fills up the cervical canal, especially during pregnancy and before menstruation is established. There are not infrequently found here small retention cysts caused by the closure of the mouths of these glands. These are the so-called ovules of Naboth, being described by Martin Naboth of Leipsic (1675–1721), who supposed them to be veritable ova.

Toward the cornua of the body the epithelium becomes less elongated and gradually merges with that of the oviducts. There is also a gradual transition at the internal os, between the epithelium of the body and that of the cervix. At the external orifice the ciliated epithelium disappears gradually, giving place to the many-layered epithelium of the vagina. The line of demarcation is, in the virgin, at the external orifice, but after repeated pregnancies it is found higher up, within the cervix.

Arteries.—The uterine artery is the principal one that supplies the organ, but blood also reaches it by the ovarian artery and the artery of the round ligament.

The uterine artery arises from the anterior trunk of the hypogastric, often in common with the superior vesical artery. It passes down along the lateral wall of the pelvis nearly to the level of the spine of the ischium, then curves forward, enters the base of the broad ligament, and proceeds almost horizontally toward the supravaginal portion of the cervix. It then ascends along the lateral border of the uterus as far as the fundus, where it curves back and enters the mesosalpinx, and divides into its terminal branches In its course it lies alongside the ureter which is on its inner side, separating it from the peritoneum. In order to reach the uterus it must cross this conduit, which it does about two centimeters from the lateral edge of the cervix, a little below the isthmus. Its pulsation can sometimes be felt during vaginal examination. Its course along the sides of the uterus is tortuous, especially in multiparæ. It gives off branches to the broad ligament and to the ureter, a cervicovaginal branch of considerable size that descends from the upper part of the vagina, numerous branches for the cervix and body of the uterus, and finally divides into two branches, one for the fundus and one for the oviduct—the internal tubal. The free anastomosis with the ovarian artery has already been mentioned. This is so free during pregnancy that some authors have considered that the ovarian vessel gives the principal supply to the uterus.

The artery of the round ligament is analogous to the external spermatic artery of the male. It is derived from the inferior epigastric artery and sends a small branch upward along the ligament to the uterus.

Veins.—The veins of the uterus are extremely numerous. They have very thin walls, so that on section they stand open and appear not unlike the sinuses of the dura mater. From the vascular layer of the uterine wall they pass out as trunks of considerable size, uniting along the edge of the organ into a rich network—the uterovaginal plexus—which extends along the entire length of the uterus and the vagina, surrounded by connective tissue and smooth muscular fibers. This discharges at the height of the external orifice into the uterine veins, which pass outward, following the general course of the artery.

Lymphatics.—The lymphatics of the uterus (Fig. 2733) arise from three plexuses: one submucous, another muscular, and a third subserous. The trunks from these all unite in the subperitoneal tissue to form a fourth plexus, from which are given off efferent trunks that reach the lumbar glands.

Nerves.—These are derived from the hypogastric ovarian plexuses of the sympathetic and from the third and fourth sacral nerves of the cerebrospinal system. The fibers are mostly of the non-medullated variety, though a considerable number of medullated fibers appear, most of them fine but some of con-

siderable size. They unite near the vaginal junction to form the uterovaginal plexus, which contains a plexiform ganglion, the cervical ganglion, or ganglion of Lee (R. Lee, 1842). Other ganglia are said to occur near the uterine attachment of the ovarian ligament. Rein found, in rabbits and guinea-pigs, numerous small ganglia about the cervix, and was led to believe that no nerves reached the organ without passing through a ganglion. This has not, as yet, been shown in the human species. As to the endings of the nerves, Gawronsky and Kalischer saw rounded and plate-like endings in the epithelium and the muscular tissue, and Herlizka describes medullated fibers that end with free dendrites in the uterine wall. These would appear to be sensitive, cerebrospinal nerves, required for reflex action.

The Vagina.—*Etymology.*—From the Latin *vagina*, a sheath or covering, particularly the scabbard of a sword. It was only occasionally and figuratively used to indicate the sexual passage. The older anatomists did not use it in this sense, but designated the organ as the *collum uteri*. Its modern use was established by De Graaf. Greek, κόλπος, a sinus, the womb; whence colpitis, colpocele, colporrhagia, etc.; also ἔλυτρον, a case, a sheath; whence elytrotomy, elytroptosis, elytroplasty, etc. French, *vagin;* Italian, *vagina;* German, *Scheide, Mutterscheide.*

Definition.—The dilatable, musculomembranous conduit that extends from the uterus through the pelvic floor to the vulva. It serves as an organ of copulation, as a passage for the evacuation of menstrual and other fluids from the uterus, and for the delivery of the child at term.

Form.—The vagina is a collapsible tube whose walls are in contact with each other, and whose cavity exists only when it is distended. In general appearance it is not unlike some parts of the alimentary canal, and it has, indeed, been called the "genital intestine." The arrangement of the apposed walls is affected by the neighboring organs. Above, where

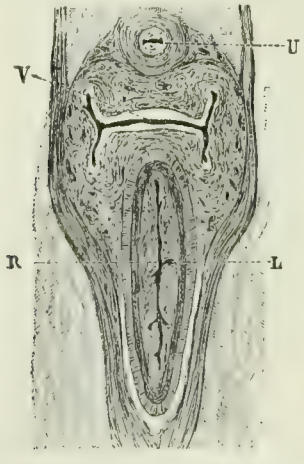

Fig. 2734.—Cross-section of the Vagina. (Henle.) *L*, Levator ani; *R*, rectum; *U*, urethra, cut obliquely; *V*, vagina.

they surround the os uteri, a transverse section shows the tube to be nearly circular; at the middle, where the muscular walls of the urethra in front and of the rectum behind impinge upon them, a section has the form of a transverse slit with vertical branches at either end, like a letter **H** with a long transverse bar (Fig. 2734); at the lower end, where the tube unites with the anteroposterior cleft of the vulva it becomes stretched in a sagittal direction, and in virgins is usually partially closed by a fold of mucous membrane termed the *hymen*. In children the tube may present a stellate appearance on section, and after frequent parturition it may become quite irregular.

When distended the cavity tapers slightly from above downward, being narrowest at its lower extremity. The widest part is, however, a little above the middle.

Division.—The upper part of the vagina, where it encircles the cervix (Fig. 2720), is known as the *fornix* or vault. This extends higher behind than in front, owing to the anteverted position of the uterus. It is usual to designate the different portions of this

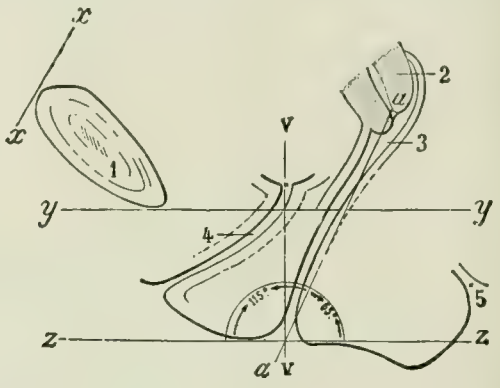

Fig 2735.—Direction of the Vagina (frozen subject, twenty-four years.) (Testut.) 1, Symphysis pubis; 2, cervix of uterus; 3, vagina; 4, urethra; 5, anus; *x*, *x*, plane of the superior strait; *y*, *y*, subpubic horizontal; *z*, *z*, horizontal drawn through inferior orifice of vagina; *v*, *v*, vertical drawn through that orifice; *a*, *a*, axis of the vagina, inclined about 60° to the horizontal.

ring-like space as the *anterior*, *posterior*, and *lateral* fornices or *culs-de-sac*. The main portion, of the tube is called the *body* of the vagina (*corpus vaginæ*); its widest part is the *ampulla*, and the entrance, visible when the labia are separated, the *external orifice* or *introitus*.

Dimensions.—Measured from the introitus to the external orifice of the uterus, the average length of the vagina is seven centimeters ($2\frac{3}{4}$ in.), varying between four or five centimeters and fourteen centimeters. This is one-fifteenth that of the entire body, exclusive of the limbs. In the new-born the length is 2.5 to 3.5 centimeters which is relatively greater, being one-ninth of the body length (Luschka). The length of the shorter or anterior wall is from 6.5 to 7.5 centimeters ($2\frac{1}{2}$ in.) while the longer, posterior wall is from 8 to 8.5 centimeters ($3\frac{1}{2}$ in.). In girls of thirteen years Symington found the anterior wall to measure 5.5 centimeters, the posterior 6.5 centimeters. The anterior cul-de-sac is shallow, being only from two to five millimeters in depth, while the posterior cul-de-sac is much deeper, being from ten to twenty-five millimeters. The vagina is susceptible of enormous dilatation without injury, enlarging sufficiently to permit the passage of the fetal head during labor. Its caliber is somewhat greater in those who have borne children.

Situation and Direction.—In its passage through the pelvic floor the vagina lies between two other great conduits: that for urine, represented by the bladder and the ureter, being in front; the alimentary canal, represented by the rectum, behind. Divergent below, these approach each other above (Fig. 2735). The vagina is usually bent backward a little below and forward above, having a course like a much elongated reversed italic *S*. It does not depart widely from the axis of the pelvic cavity, but at least half of its length is extrapelvic, being below a line drawn from the lower border of the symphysis to the tip of the coccyx. Its direction is nearly parallel to the plane of the superior strait, varying somewhat with the state of repletion of the bladder and the

rectum. Its axis makes nearly a right angle with that of the uterus when that organ is in its typical anteverted position and the bladder is not more than half full (Fig. 2727).

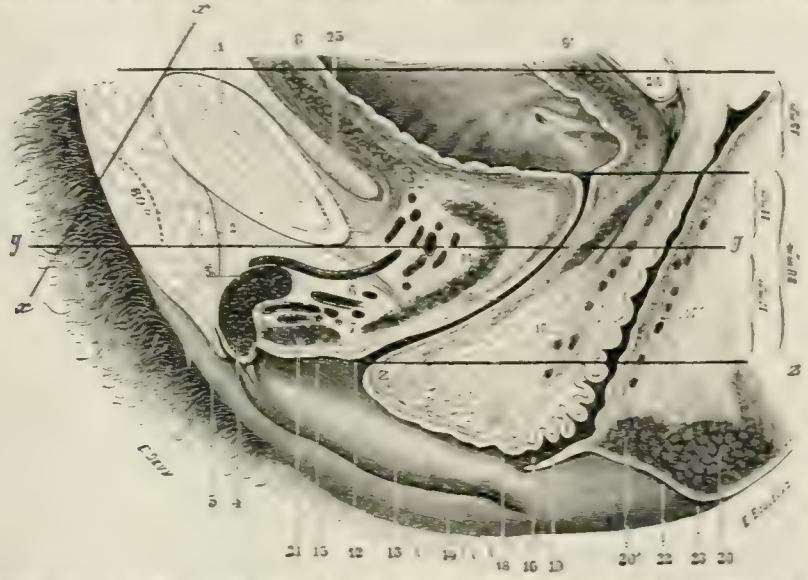

Fig. 2736.—Median Section of the Female Pelvis (subject frozen, twenty-four years old). (Testut.) 1. Symphysis pubis; 2, suspensory ligament of clitoris; 3, corpus cavernosum of clitoris; 4, glans of clitoris; 5, prepuce of clitoris; 6, dorsal vein of clitoris; 7, intermediary plexus; 8, 8', anterior and posterior walls of bladder; 9, neck of the bladder; 10, urethra; 11, external sphincter of urethra; 12, meatus urinarius; 13, labium minus; 14, labium majus; 15, vestibule; 16, inferior extremity of vagina; 17, 17', anterior and posterior columns of the vagina; 18, vaginal tubercle; 19, hymen; 20, external sphincter of anus; 20', anal extremity of the rectum; 21, fasciculi of this muscle between the rectum and the urethra; 22, fossa navicularis; 23, frenulum of the labia; 24, recto-uterine cul-de-sac; 25, pre-vesical space; x, x, plane of the superior strait; y, y, horizontal drawn through lower border of symphysis; z, z, horizontal drawn through external urethral orifice.

Fixation.—The vagina penetrates both the pelvic diaphragm (levator ani and coccygeus with associated fascia) and the genito-urinary diaphragm (triangular ligament with associated muscles) and receives support from both.

The upper part has much the same suspensory apparatus as has been already described for the cervix of the uterus. In addition, muscular fibers pass from the vagina to the sacrum behind and to the pelvis in front. Its adherence to the bladder is quite firm, but to the rectum much less, owing to the intervention of the pouch of Douglas.

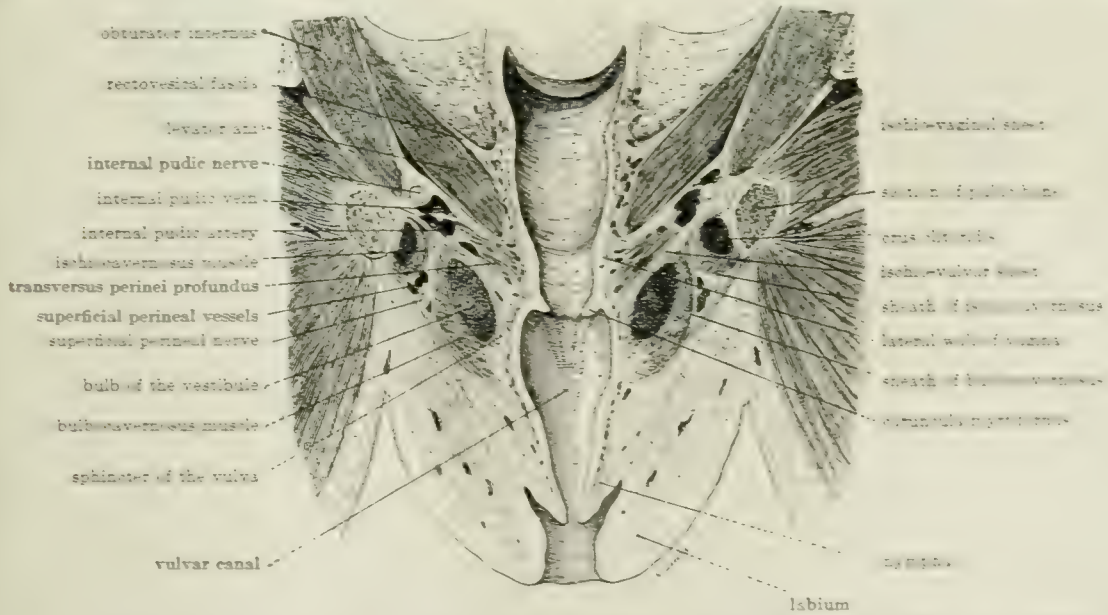

Fig. 2737.—Lower Part of a Vertical Transverse Section of the Female Pelvis, showing the Urogenital Diaphragm, the Vagina, and the External Genital Organs. (Farabeuf.) The former position of the hymen is indicated by dotted lines.

The levator ani descends from the sides of the pelvis funnel-wise (Fig. 2737), and its fibers pass

along the vagina, without becoming attached to it, to be inserted upon the rectum. They thus limit, to some extent, the displacements of the tube, without interfering with its distention.

Both sheets of the urogenital diaphragm are firmly inserted upon the vaginal walls, affording them a fixed support. In addition, the lower part of the vagina is united to the rectum by means of the perineal body and still more closely adherent to the urethra. It will be seen, therefore, that the organ is more effectively supported in its lower segments than at any other portion.

Relations.—The anterior wall may be divided into a detachable, *vesical* portion above, connected with the fundus and trigone of the bladder, and a non-detachable, *urethral* portion below. The vesicovaginal septum is about three centimeters long and wedge-shaped in vertical section, being 6–7 millimeters thick below and increasing upward. Exploration for stone is readily made along this wall, and it is here that vesicovaginal fistula forms, usually from injuries received during labor. The upper part of this septum, composed of loose areolar tissue containing numerous veins, is continuous above with the cervicovesical septum and like it can be easily separated into two layers corresponding to the related viscera. It has already been remarked that, after repeated pregnancies, there may be sufficient separation to permit the vesico-uterine fold of peritoneum to extend as far down as the upper part of the vagina. Over the trigone the tissue is denser and separation becomes more difficult, while along the urethra the two canals are so closely united that anatomical isolation becomes impossible. The urethrovaginal septum is from 5 to 12 millimeters thick.

The posterior wall is divisible according to its relations into three portions: *peritoneal*, above; *rectal*, in the middle; and *perineal* below. The peritoneal portion is from 10 to 15 millimeters in vertical extent and comprises the part in contact with the recto-uterine excavation. This may contain convolutions of the intestine, or a prolapsed ovary or oviduct. The rectovaginal septum is about four centimeters long and 3–4 millimeters thick, and contains veins and lymphatics. The two tubes are readily separable. Below this portion of closest contact the rectum bends sharply backward to end in the anal canal, leaving between itself and the vagina a space triangular in section, about twenty-five millimeters in length from above downward, and the same in thickness. This is called the perineal body and is composed of the external sphincter of the anus, the transversus perinei superficialis muscle, and the thin muscular bands called the constrictor vaginæ, all being intimately united.

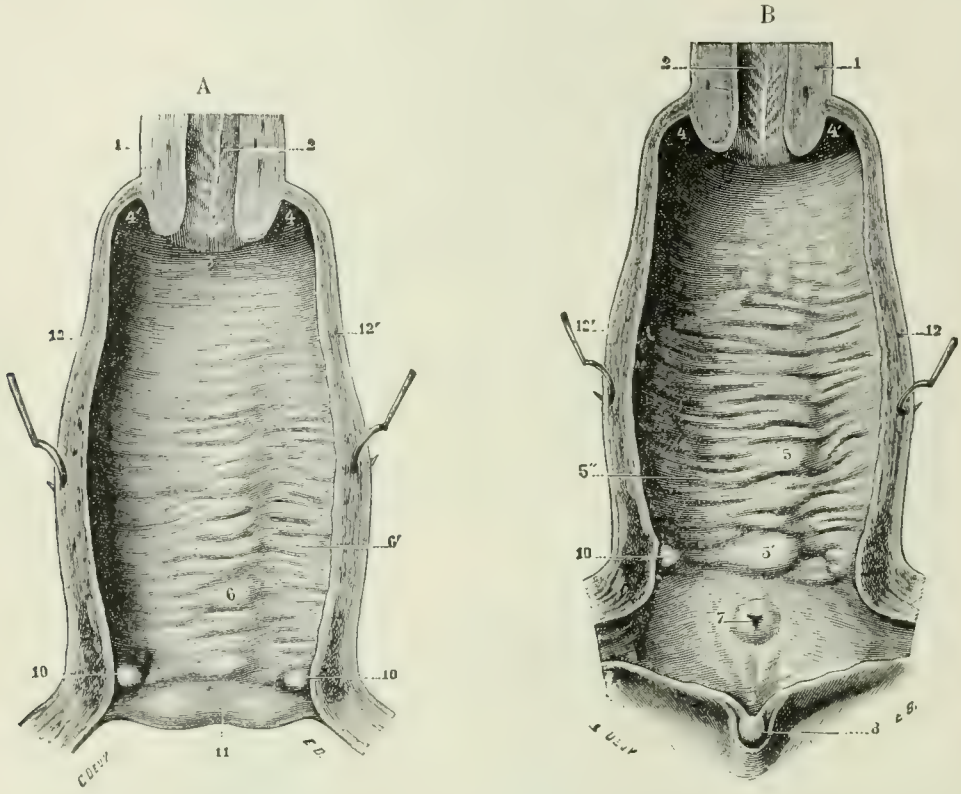

Fig. 2738.—Section of the Vagina through its Lateral Borders. (Testut.) *A*, Posterior segment showing posterior wall; *B*, anterior segment showing anterior wall; 1, cervix uteri; 2, cervical canal with arbores vitæ; 3, external orifice; 4, 4′, lateral culs-de-sac of the vagina; 5, anterior column, with 5′, the vaginal tubercle, and 5″, the transverse folds of the anterior wall; 6, posterior column, with 6′, transverse folds of the posterior wall; 7, meatus urinarius; 8, clitoris; 9, vestibule; 10, 10, caruncuiæ myrtiformes; 11, fossa navicularis; 12, 12′, sections of the lateral walls of the vagina.

Laterally we may also distinguish three portions: *pelvic*, above the levator ani; *intramuscular*, where it passes through that muscle; and *perineal*, below it. The pelvic portion is composed of areolar tissue like that which forms the parametrium, of which it is a continuation. It is often called the paravaginal tissue. Waldeyer proposes for it the term *paracolpium*, which is etymologically more correct. It contains abundant plexuses of veins surrounding the vaginal, cervicovaginal, and vesicovaginal arteries. Sometimes the loop of the uterine artery itself descends to this level, lying about fifteen millimeters outside the vaginal

wall. The ureters are at first about fifteen centimeters from the lateral cul-de-sac. As they pass forward they approach the wall and finally almost touch it anteriorly. The ganglion of Lee lies against the upper lateral portion, and remnants of the Wolffian duct, known as the ducts of Gartner, are occasionally found there. The fibers of the levator ani cross obliquely, adherent only by loose areolar tissue. By its contraction the muscle closes the vaginal passage. The tissues below this crossing belong to what is known as the urogenital diaphragm, which is composed of the two layers of fascia, here distinguished as the ischiovaginal and the ischiovulvar sheets, and the muscles which lie between them, viz., the transversus perinei profundus and the constrictor urethræ. Below the diaphragm and impinging upon the vulva are found the vulvovaginal glands and the bulbocavernosus muscle surrounding the bulbs of the vestibule, hereafter to be described.

Interior Configuration.—In the young person who has not borne children the interior of the vagina is by no means smooth (Fig. 2738). At its lower part it is crossed by transverse folds or rugæ, which thin away laterally but medially thicken to form a longitudinal elevation on both the anterior and the posterior wall. These are known as the *columns* of the vagina (*columnæ rugarum*). Both the columns and the rugæ are better developed below and on the anterior wall than above and behind. The anterior column follows quite closely the course of the urethra, and on that account is sometimes called the *carina urethralis*. It usually terminates below in a well-marked elevation, the *vaginal tubercle*, situated just behind the meatus urinarius. The column and the tubercle afford an excellent guide to the meatus in catheterization of the urethra. These elevations become gradually less marked toward the fornix and wholly disappear in the upper part of the vagina. In the fetus of eight or nine months the rugæ are found throughout the entire extent of the canal, and resemble in appearance the valvulæ conniventes

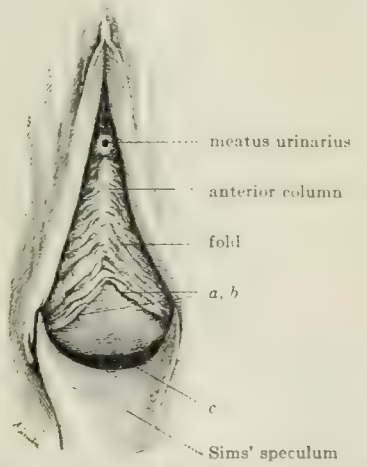

Fig. 2739.—Triangle of Pawlick. The posterior vaginal wall of a multipara strongly retracted with a Sims' speculum to show on the anterior wall the triangle of Pawlick (*a*, *b*, *c*). (Rieffel.)

of the small intestine. After considerable distention of the vagina they tend to disappear, and only traces of them can be found in multiparæ. They appear to be less frequent among some of the lower human races and are absent in apes.

The adherence of the upper part of the anterior wall to the trigone of the bladder is marked by a smooth, triangular area over which the rugæ and columns are entirely effaced. This is known as the *vaginal triangle*, or triangle of Pawlick (*area trigonalis vaginæ*, Fig. 2739). It is situated 25 or 30 millimeters below the external orifice of the uterus. Its two superior angles mark the points where the ureters enter the bladder, and are of importance as guides in the catheterization of those conduits.

In virgins the orifice of the vagina is normally partially closed by a fold developed from its posterior wall, called the *hymen* (*hymen femininus*), from the Greek ὑμήν, a membrane, not from the Latin deity who presided over marriage. Much discussion has arisen as to the morphological character of this fold. As it appears to be developed from the Müllerian duct it would seem that it must belong to the vagina. The

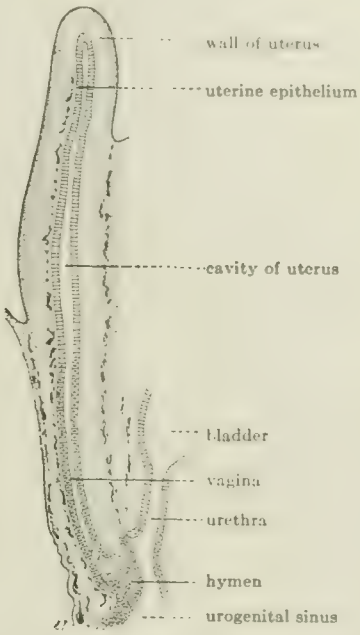

Fig. 2740.—From a Human Fetus Ten Centimeters Long. Longitudinal section passing through the genital cord. (Tourneux.)

duct is formed from a solid cord of cells by the degeneration of the centrally situated portions. At the lower end some portions of the cord persist and form the hymen (Fig. 2740).

As might be expected from its peculiar origin, the hymen varies much in its extent and shape. Some of the earlier anatomists denied its existence, and even Vesalius considered it rare. It is indeed occasionally absent altogether. Its usual form is that of an unbroken semilunar fold of sufficient size to occlude the greater portion of the vaginal orifice, leaving an opening large enough to permit the evacuation of the menstrual flow (Fig. 2741, *A*). Frequently it surrounds the orifice in a ring-like manner (*hymen annularis*), the opening being either medially or laterally situated. This opening may, however, take the form of a slit, having two lips laterally situated (*hymen bilobatus, seu bilabiatus* Fig. 2741, *C*). There may be two openings (*hymen biperforatus*, Fig. 2741, *D*), several openings (*hymen cribriformis*, Fig. 2741, *E*), or none at all (*hymen imperforatus*). This latter form requires surgical interference to effect the proper menstrual evacuation. The edges of the hymen may be variously cut (*hymen fimbriatus*, Fig. 2741, *B*), simulating the ruptures seen after defloration. The membrane may be unusually thick (*hymen carnosus*), even resembling cartilage and able to resist rupture.

It is, however, usually ruptured at the first sexual approach. It then shows irregular jagged tears, some of which reach to the outer circumference. After healing, which is not long delayed, there are produced a number of rounded nodules (*labi hymenales*)

united by thickened edges. This form (*hymen defloratus*, Fig. 2742) may be distinguished from the fimbriate variety by the character of the lacerations, which in the deflorate form usually reach the circumference, in the fimbriate are less extensive and united by fine filaments.

When labor ensues, the lobi hymenales are stretched and torn so that they afterward appear as a number of

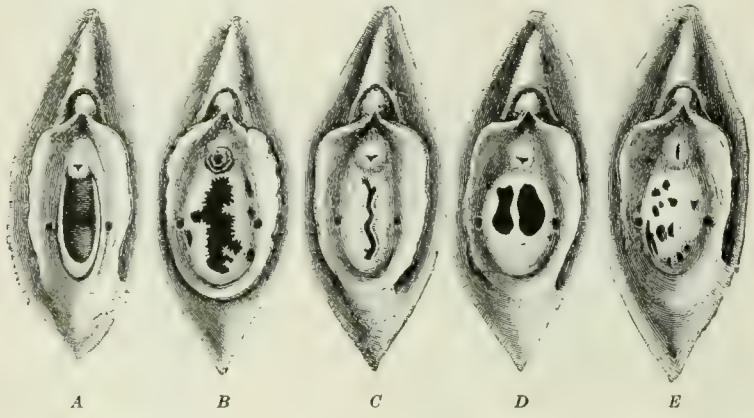

Fig. 2741.—Various Forms of the Hymen. (Testut.) *A*, Semilunar or falciform; *B*, fimbriated; *C*, bilabiate; *D*, biperforate; *E*, cribriform.

flattened, cicatrized elevations. In this state they are called the *carunculæ hymenales* or *myrtiformes* (Fig. 2744).

A hymen usually contains blood-vessels, and it is popularly supposed that its rupture is always accompanied by hemorrhage. Among the Eastern nations much reliance is placed on this "sign of virginity." The ancient Hebrews appear to have accepted it, as will be seen from Lev. xxii. 13–21. While slight hemorrhage is usual, and dangerous loss of blood has been known to occur, yet it often

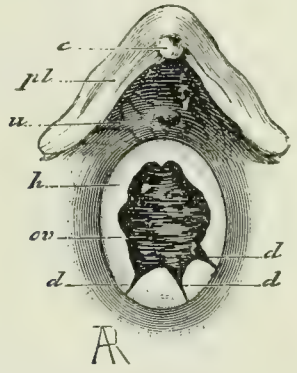

Fig. 2742.—Deflorate Hymen. Condition after first sexual approach. (Budin.) *c*, Clitoris; *pl*, nymphæ; *u*, meatus urinarius; *ov*, orifice of vagina; *h*, remains of hymen; *d*, *d*, *d*, tears.

happens that the membrane is ruptured without such signs, and pregnancy not infrequently ensues with the hymen uninjured. (Fig. 2743).

The great differences that occur in the hymen—it sometimes being torn by very slight violence, by the fingers or by some accidental circumstance, while at other times it remains intact after sexual approach and even after delivery—detract from its value as a matter of evidence in medicolegal cases. Haberda believes that it is often impossible to determine positively whether coitus has occurred. The carunculæ hymenales are more reliable, as they are found only in those who have borne children.

Structure.—We may consider the vagina as possessing three coats: external, or adventitious; middle, or muscular; internal, or mucous.

The *external* coat can hardly be said to be an intimate part of the tube, but rather the packing of connective tissue that surrounds and connects it with other organs, it being the paravaginal tissue already adverted to. It contains smooth, muscular fibers, elastic fibers, deposits of fat and contorted, vascular plexuses that give it a loose, spongy character.

The *muscular* coat is composed of smooth fibers that cannot, in all parts, be definitely separated into layers. Externally they communicate with the muscular fibers found in the paravaginal tissue. Longitudinal bands lie along the anterior wall, connecting with the bladder above. The inner fibers are, for the most part, circular. They increase greatly in size and number during pregnancy. Above, the muscular tissue is continuous with that of the

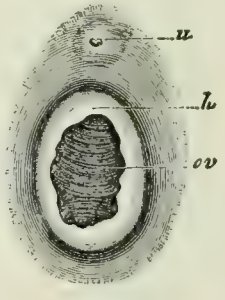

Fig. 2743.—Hymen Before Childbirth. (Budin.) *u*, Meatus urinarius; *h*, hymen whose edges are intact notwithstanding the sexual approaches.

cervix; below, it is so much thickened that some authors describe a sphincter of smooth fibers. Luschka mentions longitudinal fibers that pass to the urogenital diaphragm, constituting a *levator vaginæ*, said to elevate and dilate the vaginal orifice. A considerable amount of white fibrous and yellow elastic tissue is mingled with the muscular elements of this coat.

The mucous layer resembles the skin, being a stratified, pavement epithelium resting upon dermal papillæ. Its color is pinkish when inactive, red during menstrual or sexual excitement, and purplish red during pregnancy, when it is considerably congested. It is from 1 to 1.5 millimeters thick, quite firm and attached to the subjacent, muscular layer with-

out any intervening areolar tissue. During operations it is easily stripped off, but in that case usually carries with it portions of the muscular layer. The papillary part contains many elastic fibers, some scattered lymphoid cells, and occasional closed follicles. The mucous membrane contains no glands, and the acid mucus found on the vaginal walls is either an exudation, or, perhaps, the secretion of the uterine glands altered by bacterial agencies. A number of species of bacteria are found on the membrane, some of which appear to be peculiar to this locality.

Arteries.—These are derived from several sources. Above, the cervicovaginal branches of the uterine artery supply the fornix and upper third of the vagina; in the middle portion the vaginal artery proper, from the hypogastric, is distributed; while the lower part is supplied by a twig from the inferior hemorrhoidal, known as the inferior vaginal. The vaginal artery proper often arises in common with the uterine, the middle hemorrhoidal, or the inferior vesical. It is not unusual to find it represented by several branches. The arteries anastomose freely along the walls of the conduit and with the arteries of the neighboring organs. The arteries of opposite sides may unite to form median, anterior and posterior vessels, running longitudinally, the so-called *azygos* arteries. Deficiency in one branch of supply is usually supplemented by an increase in the others. Arterioles reach all the layers of the vagina, being especially abundant in the papillæ of the mucous membrane.

Veins.—These are so numerous that they were considered by Kobelt as forming an erectile tissue, but they lack the special characters of that structure. They are particularly developed at the sides of the vagina, forming a large plexus that is continuous with the uterine plexus above, the vesical plexus in front, and the hemorrhoidal plexus behind. Hyrtl has shown that they also communicate with the portal system by anastomosis with the superior hemorrhoidal vein. They may thus discharge in three directions: below the levator into the perineal system, above it

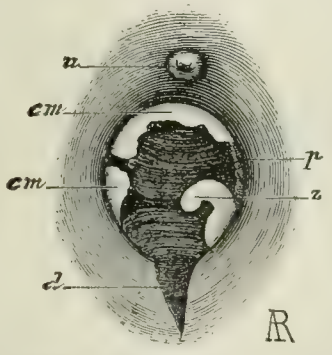

Fig. 2744.—Hymen After Childbirth. (Budin.) *u*, Meatus urinarius; *d*, tear; *cm*, carunculæ myrtiformes; *z*, detached floating tatter of the hymen; *p*, raw edge.

into the internal iliac and portal veins. Very few valves are found in these veins. They are surrounded by connective tissue and smooth muscular fibers, which cause them to remain open when cut. Hemorrhage from them is therefore difficult to stop and septic infection is easy.

Lymphatics.—Both the mucous membrane and the muscular coat contain a great number of lymphatics (Fig. 2745). The mucous coat has a fine-meshed plexus that communicates with that of the cervix above and that of the external genitals below. The muscular coat also has a plexus with much larger meshes. The two communicate freely. According to Poirier, they discharge by three groups of collecting vessels: a superior set that ends in glands that lie along the course of the external iliac artery; a middle set that terminates in glands along the hypogastric; and an inferior set that passes along the sacrum to end in glands near the promontory. By anastomoses with other vessels these may communicate with the inguinal glands. Morau states that communications also exist between the middle set and the glands within the fibrous sheath of the rectum.

Nerves.—The upper and middle portions of the vagina are supplied from the same sources as the uterus. These parts are not very sensitive. The anterior wall, particularly, can be operated on without much pain to

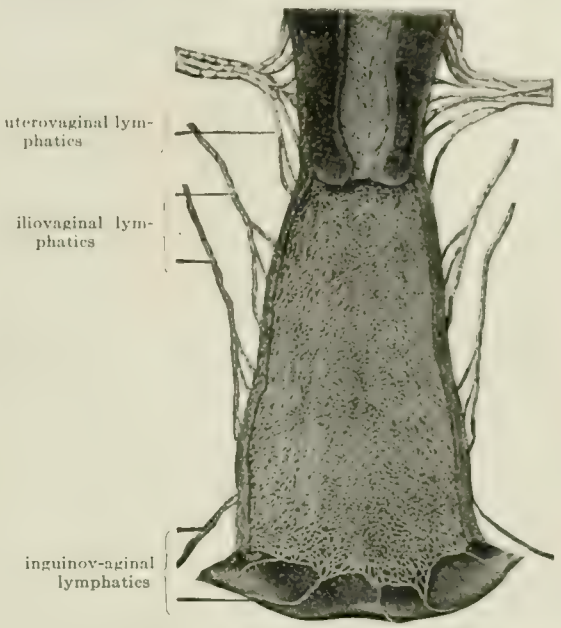

Fig. 2745.—Network of Lymphatics of the Vaginal Mucous Membrane. Efferent trunks of the vagina. (Poirier.)

the patient. The lower portion is supplied with additional filaments from the pudendal nerve, and is much more sensitive. Intraepithelial plexuses and terminations occur as in other stratified epithelium.

The Vulva.—*Etymology.*—From the vulgar Latin *vulva* or *volva*, a covering or wrap, hence the womb. Derived from *volvere*, to roll around or about. Celsus used it for the combined uterus and vagina. Spigelius derived it from the Latin *valva*, a double or folding door. The more usual Latin term for the external genitals was *cunnus*, probably derived from *cuneus*, a wedge, referring to the shape either of the mons veneris and labia as seen with the thighs closed, or of the expanded genital cleft. A synonym often used and recommended by the BNA is *pudendum*, from *pudere*, to feel shame. French, *vulve;* Italian, *vulva;* German, *Scham.*

Definition.—The external genital organs of the female, including all those derived from the urogenital sinus and found below the urogenital diaphragm. They are a series of related organs rather than the parts of a single one. Together they form an ovoid or wedge-shaped eminence situated on the surface of the body at the lower part of the abdomen, between the thighs. They include: (1) a median cleft-like space, the *vestibule*, with the vestibular glands; (2) the *labia majora* and *minora*, tegumentary folds that limit this on either side; (3) the erectile apparatus, comprising the *clitoris* and *bulbs*. Some authors use the term merely to designate the genital opening with the labia.

General Arrangement.—But little of the external genitals is visible when a female is standing erect. Only a fleshy protuberance, covered with hair, the *mons pubis*

or *mons veneris*, appears at the lower extremity of the abdomen, limited externally by the thighs and below passing into two fleshy folds, the *labia majora*, between which is seen the half-effaced end of the *rima pudendi*, or genital cleft. In some cases the end of the clitoris

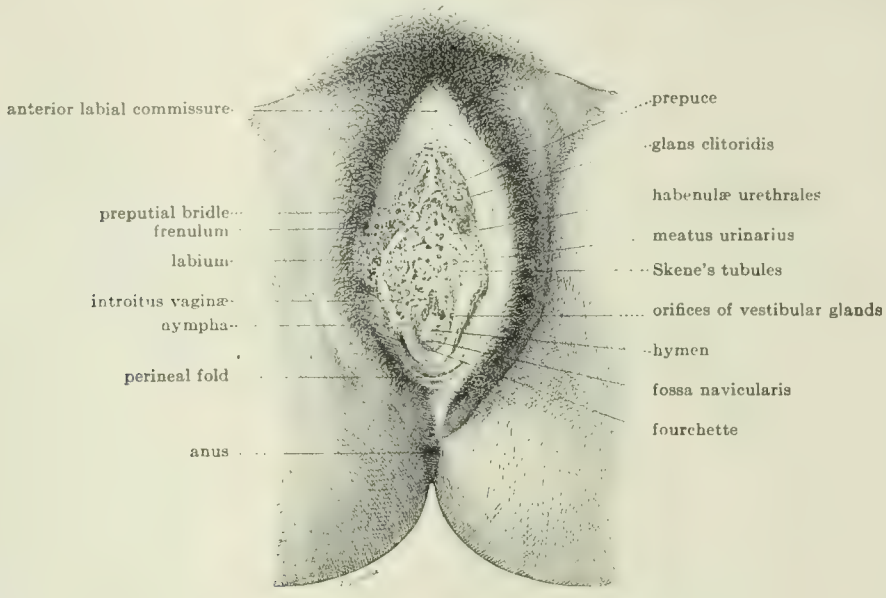

Fig. 2746.—External Genital Organs of a Virgin as seen after Separating the Labia Minora. (Rieffel.)

may protrude at the upper end of the cleft, and, still more rarely, the edges of the labia minora may be seen.

When the subject is placed in the dorsal position with widely parted thighs, flexed upon the abdomen, the genital cleft is stretched apart and forms a wedge-shaped fossa, rhomboidal in outline, limited on either side by the labia, extending in front to the mons pubis, behind to about three centimeters in front of the anus (Figs. 2746, 2747). Within this space, running parallel to the labia majora, are seen two reddish folds, the *labia minora* or *nymphæ*, which unite anteriorly by embracing a small penile appendage, the *clitoris*. The space between them is known as the *vestibule*. The vaginal orifice may be perceived posteriorly, and beneath the mucous membrane on either side of this are found masses of erectile tissue known as the *bulbs of the vestibule*.

The Vestibule.—This may be defined as the portion of the urogenital cleft that lies between the labia minora, limited in front by the clitoris, behind by the fourchette when that exists. It is not always used in this sense. Schäfer limits it behind "by a transverse line at the level of the urethra"; Gray, following the example of most French anatomists, by the en-

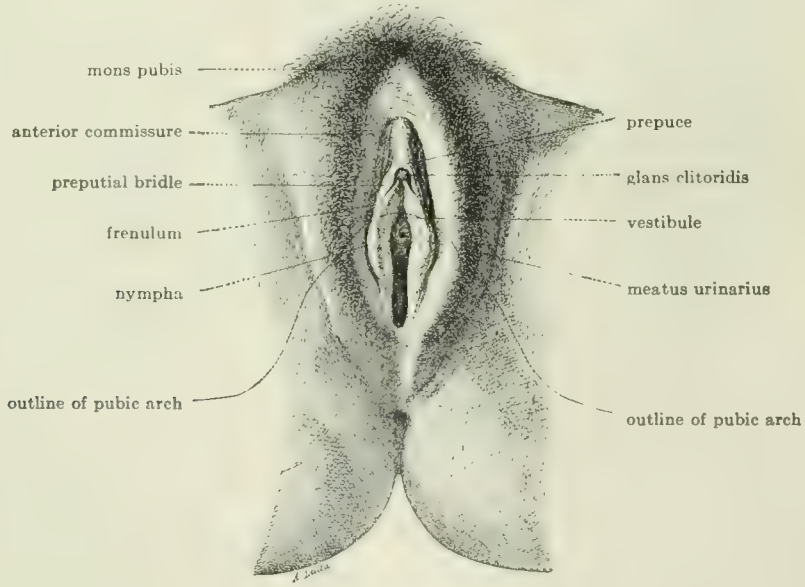

Fig. 2747.—External Genital Organs of a Multipara as seen after Slight Separation of the Labia. (Rieffel.)

trance to the vagina. If this limitation were imposed, it would hardly be proper to speak of the "bulbs of the vestibule" or of the "vestibular glands," both of which structures are situated at the sides of or behind the vaginal opening.

Like the vagina, its walls are in contact when not stretched apart. When the thighs are separated it appears as an almond-shaped space, looking downward and a little forward, its broad, rounded end being posterior. It presents a roof, two ends and sides, the latter being the inner surfaces of the labia minora.

The roof, which has in front a smooth, uniform surface, pinkish in color, presents, about the junction of its anterior and middle thirds, the external opening of the urethra. This is seated on a rounded eminence, the *urethral papilla*, which is not usually smooth, but covered with rugosities or small vegetations which may hinder the introduction of the catheter. The orifice is usually an anteroposterior slit five to six millimeters in length, but may be of various shapes, semilunar, triangular, or puckered. While it is the smallest and least dilatable portion of the urethral canal, it may, if proper precautions are used, be gradually enlarged to twenty to twenty-five millimeters or even to a greater size, without inducing incontinence of urine. Thus the finger may be introduced for exploration of the bladder, or stones and foreign bodies extracted. In some instances of absence or closure of the vagina, it is said that attempts at copulation have resulted in the introduction of the penis into the urethra. The orifice is almost vertically under the pubic arch and twenty-five millimeters from it. Its distance from the glans of the clitoris is usually somewhat less.

Running forward from the meatus to the clitoris, there may be seen in young subjects two fine whitish lines, called by Waldeyer the *habenulæ urethrales* (Fig. 2746). They represent the vestiges of the anterior part of the corpus spongiosum which, in the female, remains rudimentary. They were first noted by Pozzi (1884), who called them the "bride masculine."

On either side of the urethral orifice there may be noted the openings of two ducts for tubular glands situated on either side of the urethra and apparently homologous with the prostatic glands of the male. These ducts are often called Skene's tubules, as they were especially studied by Skene in 1880. They were, however, known to Morgagni and De Graaf.

Behind the urethral opening is found the introitus vaginæ, closed more or less in the virgin by the hymen, and showing, in multiparæ, the caruncule hymenales. The relation to the urethra borne by the anterior column of the vagina and the vaginal tubercle has been already mentioned. Since the hymen forms a membrane across the orifice of the vagina there is a slight groove formed between it and the nymphæ on either side, and this remains after the rupture of the structure. This is called the *nymphohymeneal* or *nymphocaruncular sulcus*.

In this groove, opposite the lower and middle thirds of the introitus, are seen the openings of two ducts, one on either side, which belong to glands buried quite deeply in the fatty tissue between the vestibule and the ischium. These are the *greater vestibular glands* (*glandula vestibulares majores*, Fig. 2748), often called the glands of Bartholin, from Thomas Bartholin, who discovered them in the human subject in 1680. They had previously been seen in the cow by Duverney. Our most exact knowledge of them is due to Huguier (1849), who called them the vulvovaginal glands. He described them as situated, one on either side, about one centimeter below the hymen, from 1 to 1.5 centimeters from the ischium, one centimeter from the bottom of the genitocrural fold of the integument. They are also about three centimeters from the inferior edge of the labium. By compressing the posterior part of the labium between the thumb and forefinger, a gland can usually be felt. They are acinous glands, about as large as a pea or small bean, slightly oval in shape, and discharge by a duct fifteen to eighteen millimeters long, and large enough to admit the cannula of an ordinary hypodermic syringe. They secrete a clear, viscid liquid that is discharged in considerable quantity during sexual excitement. This discharge was called by the older writers the female semen, and was long supposed to be the active generative product. It apparently serves as a lubricant to the passages during coitus. The glands attain their maximum development at puberty and atrophy during old age. They are homologous with the bulbourethral or Cowper's glands of the male. In normally developed virgins the nymphæ are united behind by a short transverse band, the *fourchette* or *frenulum pudendi*. This is ruptured at childbirth and sometimes by sexual approaches, and its relics may then be seen as a whitish scar. The shallow space between this band and the hymen, or the vaginal opening when the hymen is absent, is known as the *navicular fossa* (*fossa navicularis*). If the nymphæ are short the frenulum is absent. It should not be confounded with the artificial fold produced by widely separating the labia.

The Mons Pubis.—The genital cleft is bounded on either side by two pairs of tegumentary folds which unite in front below a rounded prominence situated directly over the symphysis pubis. This is the *mons pubis* or *mons Veneris*. It is usually separated from the general surface of the abdomen by a shallow furrow, the *pubic sulcus*, and from the thighs by the *inguinal sulcus*. Smooth, or coated with a fine lanugo in the child, as puberty approaches it becomes covered with thick and somewhat stiff hairs that have a tendency to curl. The extent of this hairy covering varies very much in different individuals, being greatest in the races of Southern Europe. Usually it descends upon either side of the labia as far as the anus. Upward it may much exceed the limits of the mons pubis and extend upon the abdomen. The hairs usually agree in color with those of the armpits and head, but they have the general appearance of those of the male beard, though usually somewhat thinner. They are spirally twisted, have a medullary canal throughout, are stronger than the hairs of the head, and show on section a triangular, irregularly fluted outline (Waldeyer).

Beneath the integument of the mons pubis is a thick cushion of fat in which are found numerous elastic fibers continuous with those of the labia and the suspensory ligament of the clitoris. These cause a gaping of incised wounds made transversely in this region.

The Labia Majora.—These tegumentary folds correspond to the scrotum of the male, and their external appearance is not unlike that organ when empty and considerably retracted. They are about twenty-five to thirty-five millimeters long, eight to fifteen millimeters in depth, and 3.5 millimeters thick. They are limited on either side by a deep extension from the inguinal furrow known as the genitofemoral sulcus. Like the scrotum their outer surface is darkly colored, somewhat roughened, and covered with hair which is extended in a scattered manner to the marginal part of the inner surface. The deeper part of this surface has the appearance of the lips of the face, being smooth, reddish and humid. The groove between it and the labia minora is called the nymphalabial furrow.

Immediately below the mons pubis the labia majora unite over the back of the clitoris (*torus clitoridis*) in an anterior commissure (commissura labiorum anterior). Behind they gradually narrow and are lost on the perineum.

Within their substance, the labia contain a layer of

smooth muscular fibers analogous to the dartos of the scrotum, a considerable quantity of connective tissue, including many elastic fibers, and subcutaneous fat. A considerable mass, called the adipose body of the labium, almost wholly fills the middle portion of the lip, resembling somewhat the fat-ball found in the cheeks of the face. It is a derivation from the subperitoneal fat with which it is often continuous along the round ligament of the uterus, which, it will be remembered, passes through the inguinal canal and is inserted here. The canal of Nuck is sometimes continued down into the labium and may be the seat of a hydrocele.

The Labia Minora or *Nymphæ.*—The latter name was introduced by Severinus Pinæus and Spigelius in the early part of the seventeenth century, "*ut enim nymphæ scaturientibus aquis præsunt,*" because, like nymphs, they control the gushing streams, it being supposed that they directed the course of the urinary jet. Though this view of their function is incorrect, the name lends itself well to combinations and ought to be retained. They are often called the labia minora or lesser lips, from their close association with the outer lips or labia proper. When the genital cleft is parted they appear as two cutaneous folds (Figs. 2746, 2747) running parallel with the labia majora, often more reddish in appearance, and not as smooth, being slightly roughened on their inner surfaces by small elevations, and often irregularly denticulated or incised on their free edges, an appearance which led Spigelius to compare them to a cock's comb. Their size varies much in different individuals. At birth they usually extrude beyond the labia, which are then but slightly developed. In the adults of European races they are ordinarily concealed, having a length of 25–35 millimeters, a breadth of 8–15 millimeters, and a thickness of 3–5 millimeters. They may, however, be large enough to extrude, and their exposed surfaces then take on a brown coloration like that of the areola of the nipple. In some African races they are enormously developed, being six to eight inches wide, extending upon the thighs to form what has been called the "Hottentot apron."

The outer surface of each nympha is separated by the nympho labial furrow from the corresponding labium majus, from which it differs by its absolute freedom from hairs. The inner surface, more rough, is in contact with the opposite nympha when the genital cleft is closed. The attached surface is in contact with the bulb of the vestibule.

The anterior extremity is continued forward and embraces the clitoris by dividing into two branches (Fig. 2748), the anterior one of which unites with its fellow of its opposite side to form for the organ a small prepuce or foreskin, similar, on a diminished scale, to the prepuce of the penis of the male. It does not usually cover the glans, but may be sufficiently developed to admit of circumcision, which is said to be practised by the Abyssinians. The posterior branch is inserted, with its fellow, on the glans of the clitoris and forms a restraining band, the *frenulum* of the clitoris. Owing to the traction of the nymphæ through this band, the clitoris is bent downward toward the vaginal orifice.

The labia minora are composed of a network of vascular, areolar tissue without fat, enclosing numerous large veins with associated, smooth, muscular fibers, which give the organ an erectile character. Its outer investment is stratified epithelium, which resembles a mucous membrane by its coloration, its smooth and humid character and its absence of hair; while, on the other hand, it resembles the skin by the character of its epithelium, which has scale-like cells that lose their nuclei, tactile corpuscles, and sebaceous glands in great numbers. In the lower animals these glands are especially active during rut, and doubtless entice the male by some characteristic odor. The epithelium becomes darker during pregnancy.

While the erectile tissue of the female genitalia is somewhat widely distributed, being found in the nymphæ and to some extent along the vagina, it is especially marked in two organs, which together are homologous with the penis of the male. These are the clitoris and the bulbs of the vestibule.

The Clitoris.—The name is neo-Latin, from the Greek κλειτορίς, said to be derived from κλείειν, to close or shut. Hyrtl thinks it is related to κλειτορίζειν, to titillate. This would be analogous to *Kitzler*, the German vernacular name for this organ.

It represents a small appendage, resembling a diminutive penis, suspended at the summit of the pubic arch (Figs. 2746–2750) and enfolded by the anterior juncture of the nymphæ. Like the penis it possesses two corpora cavernosa, small rods of erectile tissue, united in front to form the *body* of the organ, diverging behind as its *crura*. The body

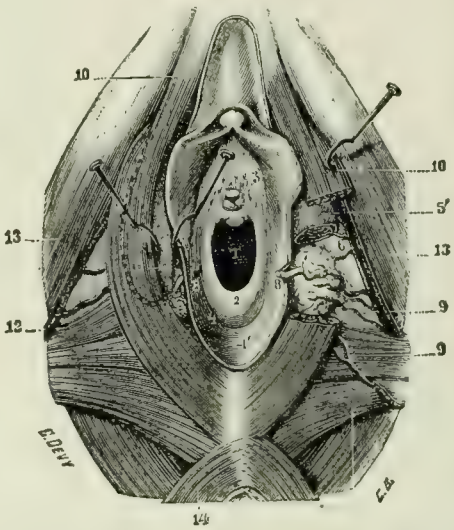

Fig. 2748.—Dissection of the Vulva, showing the Vestibular Glands. 1, Orifice of the vagina: 2, hymen; 3, meatus urinarius; 4, navicular fossa; 5, bulb of the vestibule; 6, vestibular or vulvovaginal glands; 7, 8, duct; 10, constrictor vaginæ; 11, transversus perinei muscle.

is crowned with a small *glans*. Unlike the penis, the glans is not perforated by the urethra, and there is no corpus spongiosum attached to it. When lax the organ is so withdrawn within the folds of the nymphæ and labia that it is difficult to make out its form and dimensions.

The crura are attached on either side to the inner aspect of the pelvic arch, half-way between the tuberosity of the ischium and the symphysis. Wholly hidden within the folds of the labia, they pass forward, inward, and a little upward, along the external face of the triangular ligament, surrounded by the ischiocavernosus muscle (*erector clitoridis*) and join each other below the symphysis to form the body, room being left between their junction and the arch to permit the passage of vessels and nerves.

Almost immediately the body is bent downward and backward, forming what is called the *angle* of the clitoris. Unlike the angle of the penis, this does not become obliterated when the organ is erect, and this doubtless subserves the function of the organ. Movements are prevented by the frenulum, which, as already mentioned, draws the glans down toward the vaginal orifice, and by the *suspensory ligament*, a fibrous band like the similar organ of the penis, that passes from the angle to the linea alba.

The body of this little organ is nearly cylindrical in shape, usually slightly grooved on its under surface because of its duplex structure. An imperfect division or *septum pectiniforme* separates the two lateral

halves. Females of animal species in which the males possess a penis bone have sometimes a minute bone or cartilage in this septum. The greater part of the body is concealed under the anterior commissure of the labia, its swollen outline forming the *torus clitoridis*.

The glans, which terminates the organ, is a small, rounded, conoid tubercle. It is independent of the corpora cavernosa, capping over their fusiform ends as in the penis. It has a small prepuce derived from the nymphæ, and a preputial sac in which small collections of smegma may accumulate. To its under surface is attached the frenulum.

pansion of the arterial orifices through the action of vasodilator nerves, and the impeding of the venous discharge by the ischio-cavernosus muscle and the elastic envelope. This apparatus is by no means as well developed as in the corresponding organ of the male, consequently erection is less complete.

The glans has no albuginea, but under its epithelium is a considerable fibroelastic network which performs a similar function. Areolæ occur and the vascular supply is similar to that of the corpora cavernosa. Its cutaneous investment is supplied with special nerve endings, which give it remarkable

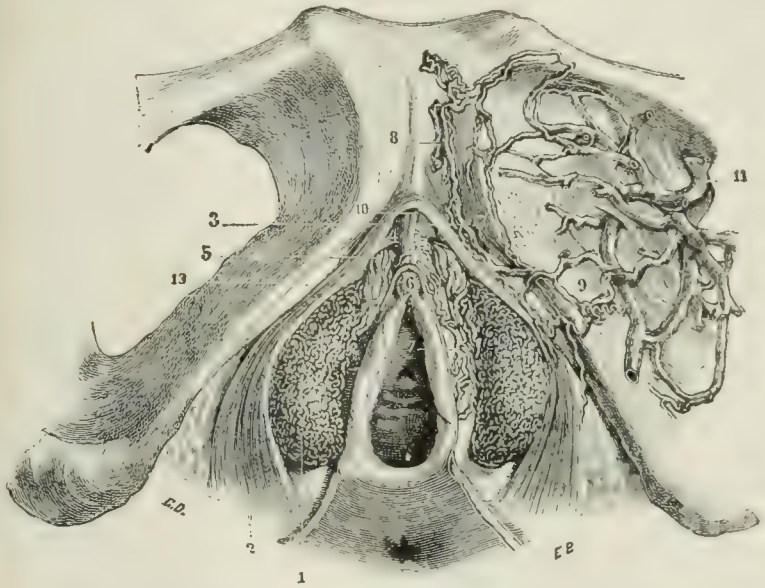

Fig. 2749.—The Bulb of the Vestibule and the Venous System of the Clitoris seen from the Front. (Kobelt.) 1, Bulb of the vestibule; 2, constrictor vulvæ muscle; 3, anterior portion of same; 4, portion that passes under the clitoris; 5, pars intermedia; 6, glans of clitoris; 7, veins from nymphæ; 8, veins passing to superficial veins of abdomen; 9, veins communicating with the obturator vein; 10, dorsal vein of clitoris; 11, obturator vein; 12, body of clitoris; 13, right crus of clitoris.

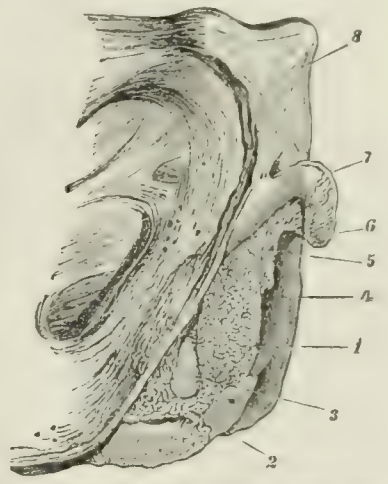

Fig. 2750.—Bulb of the Vestibule and the Clitoris Seen from the Side. (Kobelt.) 1, Right bulb of the vestibule; 2, veins from its lower end that discharge into the internal pudic vein; 3, vestibular gland; 4, introitus vaginæ; 5, pars intermedia; 6, glans clitoridis (the clitoris is somewhat elevated); 7, dorsal vein of clitoris; 8, symphysis pubis.

The following measurements of the clitoris are given by Krause:

	When relaxed	When erect.
Length of body	18 mm.	29 mm.
Thickness of body	5 mm.	9 mm.
Length of crura...	40 mm.	45 mm.
Thickness of crura	5 mm.	8 mm.
Diameter of glans.	4–7 mm.	6–9 mm.
Total volume.....	2 c.c.	6 c.c.

Considerable individual variations are found. The organ may be of such size as to be mistaken for a small hypospadiate penis, and thus lead to mistake in determining the sex of a child.

The structure of the clitoris repeats, on a diminutive scale, that of the penis. Each corpus cavernosum is surrounded by a firm, elastic, fibrous envelope, the *tunica albuginea*, from whose deep surface are given off numerous bands of trabeculæ, along which run smooth, muscular fibers. These trabeculæ divide the substance of the organ into numerous small spaces, termed areolæ, which are really venous sinuses, as they are lined with endothelium and communicate widely with the veins. Into these areolæ empty arterioles (helicine arteries). Erection occurs from the rapid filling of the areolæ by the ex-

and special sensibility. According to Dogiel there are intraepithelial plexuses with filaments ending in flattened platelets, tactile corpuscles within the papillæ, corpuscles of Pacini and the end bulbs of Krause in the subcutaneous tissue, while at the base of the papillæ are the special endings which Krause believes to be related to the peculiar sensibility of the organ and has named corpuscles of sexual pleasure (Wollustkörperchen). They are usually called genital corpuscles.

The Bulbs of the Vestibule.—The corpus spongiosum urethræ of the male, including the bulb of the urethra, is represented in the female by two oval masses of erectile tissue that lie beneath the nymphæ on either side of the vestibule and in front of the triangular ligament (Figs. 2749, 2750). Their lower ends are free, but they are united above over the lower end of the urethra, thus simulating the form of a horseshoe set astride of the vaginal opening. They were called by De Graaf *corpora retiformia*, by Taylor *semibulbi corporis spongiosi*, but, since the time of Kobelt (1844), are generally known as the *bulbs of the vestibule* (*bulbi vestibuli*). They should be considered as the male organ separated into two portions by the intrusion of the vaginal opening in the median line.

Enlarged and rounded at their lower extremities, they are bulb-like in form. Their shape has also been compared to that of an almond, a fig, or, still more aptly, to that of an engorged leech, which they closely

resemble because of their long, tapering, upper extremities which unite with each other and with the clitoris. Their dimensions vary in different individuals. Usually reaching as far back as the navicular fossa, they may not extend beyond the middle of the vaginal opening, or, on the other hand, they may be continued behind on to the perineum. When not turgid, each bulb is, in ordinary cases, about 30 to 40 millimeters long, 10 to 15 millimeters broad, and 5 to 10 millimeters thick.

The bulbs are only about eight to ten millimeters from the pubic arch, but are so situated with regard to the vaginal opening that they are pushed forward and away from the bones as the fetal head descends. Rupture of one of them may, however, occur during labor, especially if instruments are used. This occasions a large hematoma in the corresponding labium, or, if the rupture extends through the entire integument, a serious hemorrhage.

The upper or deeper surface of the organ is applied to the ischiovulvar or outer sheet of the urogenital diaphragm, to which it is attached by some lax, areolar tissue. Its inferior or superficial surface is covered by the basis of the nymphæ. Like the bulb of the urethra in the male, it is invested externally by a sphincter muscle, the bulbocavernosus, which, by the separation of the two bulbs, becomes applied to the outer surface only, forming a constrictor of the vagina. Its internal surface embraces the vestibule, skirting the orifice of the urethra, the vagina, and the vestibular glands. Its anterior extremity, pointed and drawn out, communicates above the opening of the urethra with the glans of the clitoris and with the opposite bulb. The plexus thus formed was called by Kobelt the *pars intermedia*. It lies immediately under the habenulæ urethrales, and with them constitutes a vestige of the corpus cavernosum urethræ of the male.

In structure the bulbs resemble the corresponding organ of the male. They are invested by a thin tunica albuginea, within which is a plexus of large veins surrounded by muscular fibers sparsely distributed. The organ has the general structure of erectile tissue, but is much less perfect in that function than the clitoris, and very far below the male penis. When engorged with blood it assumes a swollen doughy consistence rather than a complete rigidity. It is supplied by the artery of the bulb from the internal pudendal. The blood, after leaving the plexus of veins found in the organ, passes into the pudendal perineal, and clitoridian veins.

Arteries.—The arterial supply of the vulva is shown in the following scheme:

Arteries.	Distribution.
From the common femoral artery—	
Superior external pudendal	Small branches to the mons pubis and anterior commissure of the labia.
Inferior external pudendal	*Anterior labial* branches to anterior half of labia majora, some of which reach the nymphæ.
From the internal pudendal artery	
Dorsal artery of the clitoris.	Glans clitoridis and anterior part of nymphæ, a few twigs extending upward to the mons pubis.
Artery of the corpus cavernosum.	Crura and body of clitoris, small branch to bulbs of the vestibule.
Artery of the bulb.	Bulbs of the vestibule, meatus urinarius (*urethral artery*), vestibular glands.
Perineal.	*Posterior labial* branches to posterior half of labia and nymphæ, bulbs of the vestibule, vestibular glands.
Transverse perineal...	Posterior end of labia, navicular fossa.
From the obturator artery	
Internal terminal branch	*External labial*, to outer suface of labia.

Veins.—With one exception these have the same general arrangement as the arteries, discharging into the great saphenous, the internal pudendal, and the obturator trunks (Fig. 2749). The dorsal vein of the clitoris discharges into the pudendal plexus (plexus of Santorini), whose efferent vessels terminate in the hypogastric vein. Numerous venous plexuses occur in the different organs. Thus the areolæ of the clitoris themselves constitute a plexus, the veins of the bulbs of the vestibule are arranged in a superficial large-meshed plexus and a deep, fine-meshed one, and a plexus also exists within the labia minora. These communicate freely with each other and with the vesical and vaginal plexuses.

Lymphatics.—The lymphatic vessels of the external genitals are very numerous, especially upon the nymphæ and the inner surface of the labia majora. They discharge, for the most part, into the superior internal or pubic group of superficial inguinal glands. This group lies internal to the fossa ovalis and near the spine of the pubis. It includes two to four glands. Some vessels may discharge into the inferior internal group of superficial glands, or even, though rarely, reach some of the external group. In injecting the lymphatics on one side of the vulva, it is often found that the injection reaches the opposite side.

Cunéo and Marcille have recently shown that the lymphatics of the glans of the clitoris ascend by way of the mons pubis to the inguinal canal, through which they pass, to terminate in glands situated along the iliac vessels.

Nerves.—The nervous supply of the vulva is derived both from the cerebrospinal and from the sympathetic systems. The cerebrospinal nerves come from both the lumbar and the sacral plexuses, the sympathetic from extensions of the hypogastric plexus known as the cavernous and the uterovaginal plexuses. From the first are given off two nerves, the greater cavernous nerves, and a number of small nerves, the lesser cavernous nerves that supply the crura, body, and glans of the clitoris. The nervous supply of the organ is far greater, in proportion to its size, than that of the penis. With the cavernous plexus are distributed the branches from the third and fourth sacral nerves that effect erection, the *nervi erigentes* of Eckhard. Other nerves from the the cavernous plexus combine with the cerebrospinal nerves, whose distribution is given in the following scheme:

Nerves.	Distribution.
From the lumbar plexus.	
Iliohypogastric—	
Anterior cutaneous branch	Integument upon upper part of mons pubis.
Ilioinguinal—	
Inguinal branch...	Integument upon lower part of mons pubis and upper part of labium.
Genitocrural—	
Genital branch	To labia (anterior labial nerves),
From the sacral plexus.	
Pudendal—	
Perineal branch.....	To labia (posterior labial nerves). nymphæ, prepuce and glans of clitoris, vestibule and meatus urinarius (nerve of vestibule), bulb of the vestibule.
Dorsal nerve of clitoris	Glans, prepuce, body and crura of clitoris.
Posterior femoral cutaneous—	
Inferior pudendal branch.	To labia (posterior labial nerves).

FRANK BAKER.

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Genital Organs, Male.—Embryology.—In order to have a proper knowledge of the normal and at times abnormal anatomy of the human male genital organs, it is essential that a brief review of the main facts of their embryology should be presented.

That the higher types of vertebrates, during their development, pass through stages the essentials of which are permanent in some of the forms below them, is particularly well exemplified by a study of the embryology of the genital organs.

In the light of the theory of development many cases of anomaly of the genital organs will furnish striking evidence of either *atavism* or *arrested development*. In the growth of the embryo there is at first a period during which there is no indication of any provision either for a urinary or a generative function. A little later the rudiments of a urogenital apparatus are developed, but as yet there is no evidence of sexual differentiation.

In the course of embryological changes it will be observed that certain of the structures concerned appear and assume their permanent characters. Gradually and without modification of plan other structures, at first employed for purposes unrelated to the urogenital apparatus, become adapted, secondarily, for special purposes in this system; others, though belonging to this system from the first and attaining to a condition of functional activity in one direction, are later adapted to altogether different activities in another direction; lastly, other rudiments, according to the sex developed, either become elaborated into efficient and important parts of the reproductive organs, or dwindle into useless vestiges that never take any part in the normal work of the body.

In order that the reader may appreciate, to some extent, the significance of references to the lower animals, it may be well to state here that Tunicates are the lowest vertebrates known. Then, according to the grade of organization and from the simpler to the higher, come, in order, the Acrania (Amphioxus), Cyclostomes, Fishes, Amphibians, Reptiles and Birds, and, highest of all, the Mammals. The Mammals are further subdivided, according to grade of organization, into the Monotremes, Marsupials, and Placentals.

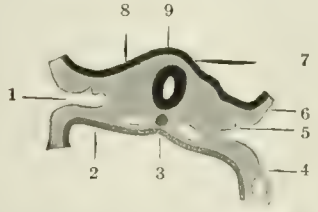

Fig. 2751.—Transverse Section of a Seventeen-day Sheep Embryo. Diagrammatic. 1, Cœlom (pleuroperitoneal cavity); 2, entoderm; 3, notochord; 4, splanchnic mesoderm or mesoblast; 5, middle plate; 6, somatic mesoderm or mesoblast; 7, ectoderm; 8, neural canal; 9, paraxial mesoblast.

The common embryonic foundations of the sexual organs, male and female, are as follows, viz., for the internal organs of generation they are the *germinal gland*, *the Wolffian duct*, the *mesonephros*, the *Müllerian duct*, a part of the *intraembryonic allantois*, a part of the *cloaca*, and a part of the *proctodeum* (Figs. 2752 and 2753).

For the external organs of generation they are the *genital eminence*, *genital groove*, *genital folds*, and *genital ridges* (Figs. 2756 and 2757).

In intimate relation with the Wolffian duct arise, in orderly sequence, three important structures—viz., the *pronephros* or head kidney, *mesonephros* or Wolffian body (mid-kidney), and the *metanephros* or hind (permanent) kidney (Fig. 2752).

These nephric structures all lie in the dorsal wall of the embryo's abdominal cavity (celom) near the point where the somatic and splanchnic layers join (Fig. 2751); they extend, on either side of the notochord (primitive vertebral column), from the neighborhood of the heart to the tail end of the embryo, one behind the other in the order indicated by their names.

The intestinal, urinary, and reproductive organs are not only intimately related in the adult, but they are still more intimately related in the embryo (Fig. 2752), and therefore they must be referred to, in varying degrees, in describing the development of the male sexual apparatus.

At an early stage of the embryo an evagination occurs from the ventral surface of the hind gut near its caudal end to form the *allantois* (Fig. 2752, *A*). The part of the hind gut caudad of the allantois is the *cloaca* (*Cl*). The cloaca is present permanently in all vertebrates from Fishes to Monotremes.

Development of the Internal Genital Organs.—The pronephros and Wolffian duct are evolved as follows: the mesothelial cells of the *somatic mesoderm* (Fig. 2751, No. 6) near the *middle plate* (No. 5) evaginate on both sides, and form a cord of cells parallel with the notochord; at several points along the cephalic extremity of this longitudinal cord of cells it retains its connection with the lining cells of the celom (abdominal cavity) by short transverse cords of cells. Soon the cell cords are hollowed out, and thus are formed the segmental or Wolffian duct (Fig. 2752, *W*), which passes caudad and empties into the *cloaca* (*Cl*), and several short transverse *tubules* (Nos. 1, 1, 1), opening at one end into the celom and at the other extremity into the Wolffian duct. The transverse tubules in the immediate neighborhood of their celomic extremities are evaginated by a tuft of capillary blood-vessels from a branch of the adjacent axial blood-vessel (aorta), so that a series of *glomeruli* are formed. Through the physiological activity of the cells of the glomeruli the urinary constituents are eliminated in the Anamnia from the blood and passed along the transverse tubules into the Wolffian duct and cloaca and thence evacuated from the body. It is thus seen that the transverse tubules and their glomeruli constitute a segmental primitive kidney (pronephros). This pronephros (Fig. 2752, Nos. 1, 1, 1), though functional in Cyclostomes, Teleosts, and larval Amphibians, is vestigial in Selachians, Reptiles, Birds, and Mammals, and never functionates as a urinary organ; it soon gives place to the more important *mesonephros* (Fig. 2752, Nos. 2, 2, 2, 2).

Simultaneously with the segmentation of the paraxial mesoderm (Fig. 2751, No. 9) into the somites, the *middle plate* undergoes segmentation, and each segment is called a *nephrotome*. In the lower vertebrates each nephrotome is hollow and is formed by evagination of the celomic mesothelium; but in Reptiles, Birds, and Mammals the nephrotomes are at first solid cords of cells which subsequently become hollowed out and converted into a series of transverse, short canals situated behind, caudad of, the pronephros. They soon acquire connection with the previously formed Wolffian duct. Collectively they constitute the Wolffian body or *mesonephros*. At the cephalic end of the Wolffian duct, the now atrophied transverse tubules and glomeruli of the pronephros are still in connection with it. Embryologists usually compare the mesonephros with its Wolffian duct to a comb, the duct corresponding to the back of the comb, and the short transverse tubules representing the teeth.

In the further development of the mesonephros each transverse tubule becomes somewhat saccular midway between its two extremities, and then the sacculated portion is invaginated by a tuft of capillary blood-vessels derived from an arterial branch of the aorta. The invaginating tuft of capillaries is known as a Malpighian tuft, while the invaginated portion of the transverse tubule is called the Malpighian

capsule; the two together constitute a primitive Malpighian body, analogous with the Malpighian bodies of the permanent kidney or metanephros. By the development of secondary tubules and Malpighian bodies the complexity of the mesonephros is greatly increased.

In those vertebrates in which the pronephros attains to a temporary functional activity, as in Cy-

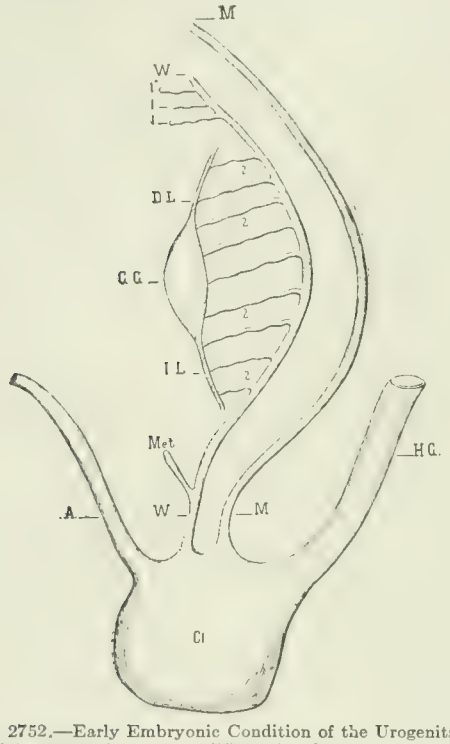

Fig. 2752.—Early Embryonic Condition of the Urogenital System. Diagrammatic. Sex undifferentiated. *A.*, Allantois; *Cl.*, cloaca; *H. G.*, hind gut; *W.*, Wolffian duct; *M.*, Müllerian duct; 1, 1, 1, pronephros; 2, 2, 2, 2, mesonephros (Wolffian body); *Met.*, metanephros (rudimentary permanent kidney); *G. G.*, germinal gland; *D. L.*, diaphragmatic ligament; *I. L.*, inguinal ligament.

clostomes, Teleosts, and Amphibians, the mesonephros appears relatively late; on the contrary, in those animals in which the pronephros remains rudimentary, as in Sharks, Reptiles, Birds, and Mammals, the mesonephros is developed early.

In the Anamnia (Fishes and Amphibians) the mesonephros not only acquires relations with the sexual apparatus, but also functionates as a urinary organ. Hence in these animals there is no metanephros. In the Amnia (Reptiles, Birds, and Mammals) the mesonephros functionates as a urinary organ only a short period during embryonic life; it undergoes profound retrograde and adaptive changes soon after its formation and enters into the exclusive service of the sexual apparatus, serving as channels to conduct the sexual cells from the germinal glands in the male, and becoming entirely vestigial in the female (parovarium and paroöphoron).

The transverse tubules of the mesonephros are divisible, in man, into an anterior or cephalic series and a posterior or caudal set. The former are the *sexual* set, and the latter become vestigial as the paradidymis and vas aberrans (homologous with the paroöphoron of woman) (Fig. 2754).

In the Amnia the permanent urinary organ is the metanephros. While the mesonephros and its Wolffian duct are temporarily functionating as a kidney, an evagination occurs from the caudal extremity of the duct.

This evagination soon lengthens into a tube (Fig. 2752, *Met*), which extends cephalad, toward the caudal part of the mesonephros. The cephalic end of the rudimentary metanephros branches freely to form a number of smaller tubes. The surrounding undifferentiated mesodermic cells form enveloping connective and vascular tissue. The blind end of each little tube becomes dilated and then invaginated by a tuft of capillary blood-vessels so that Malpighian bodies are formed analogous to those in the pro- and mesonephros. The tubules, owing to excessive growth in length, become tortuous and convoluted. The stalk of the diverticulum becomes the *ureter*, while the dilated part from which the branches are given off differentiates into the pelvis of the kidney with its infundibula and calyces.

Shortly after the formation of the mesonephros another tube (*Müllerian duct*) appears (Fig. 2752, *M.*). It lies close to the outer side of the Wolffian duct and parallel with it. It arises by evagination of the mesothelium of the celom in the form of a solid cord of cells and later acquires a lumen. The cephalic end of the duct, near the pronephros, maintains a communication with the celom by means of an expanded funnel-shaped mouth, while the caudal part empties into the cloaca. Its lower segment becomes closely

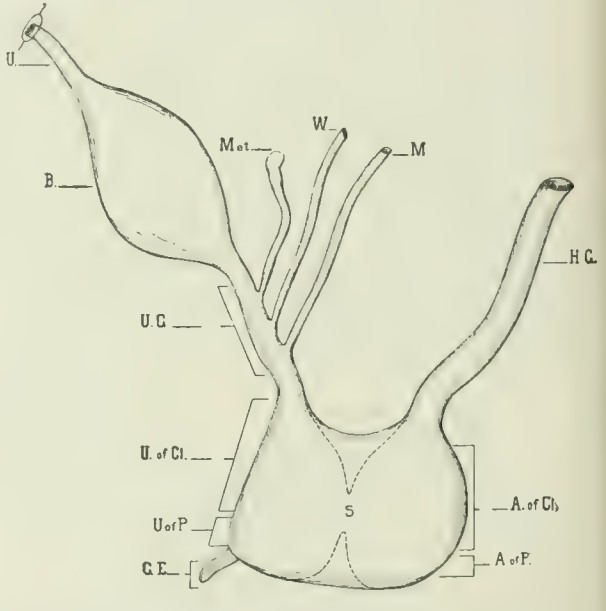

Fig. 2753.—Embryonic Condition of the Urogenital System Later than that Represented in Fig. 2752. Diagrammatic. The allantois has differentiated into the urachus (*U.*), bladder (*B.*), and urogenital sinus (*U. G.*). The proctodeum has appeared and, with the cloaca, is undergoing subdivision by the formation of the perineum (*S.*). *U. of Cl.*, Urogenital part of the cloaca; *U. of P.*, urogenital part of the proctodeum; *A. of P.*, anal part of the proctodeum; *A of Cl.*, anal part of the cloaca; *H. G.*, hind gut.; *G. E.*, genital eminence; *Met.*, metanephros (permanent kidney); *W.*, caudal part of the Wolffian duct; *M.*, caudal part of the Müllerian duct.

associated with its fellow of the opposite side and with the two Wolffian ducts, thus forming the *genital cord*. The cloacal segments of the Müllerian ducts fuse early into a common tube, except in the Monotremes, where they remain permanently separate and empty into the urogenital sinus (Fig. 2753, *M.*). In all other Mammals they fuse to a greater and greater degree in the ascending mammalian scale. Varying degrees of reversion to the more primitive types occur as instructive anomalies in human anatomy.

In the ascending vertebrate scale, the Wolffian duct

first appears in Cyclostomes, the Müllerian duct in Elasmobranchs, and the metanephric ureter in Reptiles.

This is a convenient place to state that the intra-embryonic portion of the allantois—in other words, that portion extending from the umbilicus to the cloaca—becomes differentiated into three segments as follows: The middle part dilates to form the *bladder* (Fig. 2753, *B.*), the umbilical portion becomes the *urachus* (*U.*), and the cloacal segment differentiates into the *urogenital sinus* (*U. G.*).

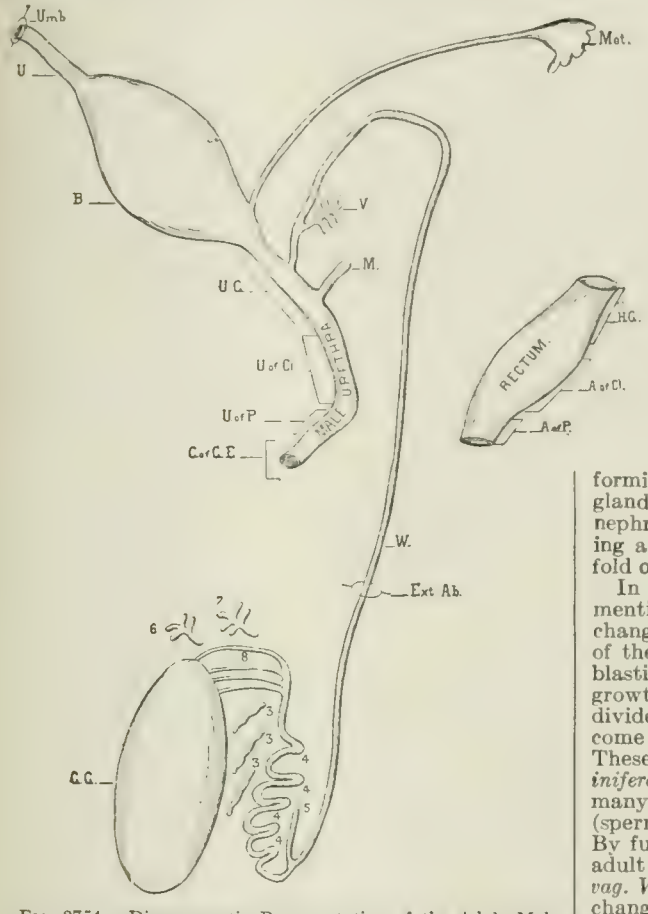

Fig. 2754.—Diagrammatic Representation of the Adult Male Urogenital System. Illustrating especially the embryonic elements that enter into the formation of the male urethra, the epididymis, and the rectum. The testicle (*G. G.*) and its related but much modified mesonephros (3, 3, 3, 4, 4, 4, 4, 5, 8) have descended from the abdominal cavity into the scrotum. *Umb.*, Umbilicus; *U.*, urachus; *B.*, bladder; *U. G.*, prostatic urethra (urogenital sinus); *U. of Cl.*, together with *U. of P.*, form the membranous urethra (*U. of Cl.* is the urogenital part of the cloaca, and *U. of P.* is the urogenital part of the proctodeum); *C. of G. E.*, spongy urethra (canal of the genital eminence); *Met.*, permanent kidney (metanephros) and ureter; *V.*, vesicula seminalis; *M.*, uterus masculinus (distal vestige of Müllerian duct); *W.*, vas deferens (Wolffian duct); *Ext. Ab.*, external abdominal ring; 6, sessile hydatid (proximal vestige of Müllerian duct); 7, stalked hydatid (vestige of pronephros); 8, globus major of the epididymis; 4, 4, 4, 4, body and globus minor of the epididymis continued into the vas deferens (*W.*); 8, 4, 4, 4, 4, sexual adaptations of the mesonephros; 5, vas aberrans (vestige of mesonephros); 3, 3, 3, paradidymis (non-sexual vestige of mesonephros); *G. G.*, testicle or didymis (germinal gland); *A. of P.*, anal part of proctodeum; *A. of Cl.*, anal part of cloaca; *H. G.*, hind gut. Compare the male urethra with the female urethro-internymphal channel (Fig. 2755, 1, 2, 4, 5, 6).

Through unequal growth of the parts the Wolffian and Müllerian ducts shift their positions from the cloaca to the urogenital sinus (Figs. 2752 and 2753), and also the duct (ureter) of the metanephros (permanent kidney) shifts its position from the Wolffian duct, first, to the urogenital sinus (Fig. 2753, *Met.*), and, finally, to the base of the bladder (Fig. 2754, *Met.*). Only in the Monotremes, among Mammals, do the ureters open permanently into the urogenital sinus.

In the twelfth week of the embryo the urogenital sinus acquires thick muscular walls, and the lining epithelial tube evaginates into the muscular tissue in the form of little sacs, the lining cells of which differentiate into secreting epithelium. Thus is formed the *prostate gland* enveloping the urogenital sinus or, as it is now designated, the *prostatic urethra*. The prostatic urethra is homologous with the *urethra* and the proximal part of the *internymphal space* of the adult female (Fig. 2755). The musculo-glandular part of the prostate is possibly homologous with the musculo-glandular part of the uterus. In this connection it is interesting to note that castration leads to atrophy of the prostate and removal of the ovaries induces atrophy of the uterus.

While the Müllerian duct is developing, a thickening of the mesothelial cells of the celom occurs close to the ventromesial portion of the mesonephros, thus forming an elongated swelling (*germinal ridge*) on the wall of the celom. By the proliferation of the mesoblastic tissue beneath the mesothelial cells the germinal ridge is still further enlarged, ultimately forming the *germinal gland* (Fig. 2752, *G. G.*). The gland becomes gradually pinched off from the mesonephros as the embryo grows, though still maintaining a connection with the vestige of this body by a fold of peritoneum (mesorchium or mesovarium).

In the differentiation of the male from the above-mentioned indifferent fundiments the following changes take place, viz.: columns of mesothelial cells of the germinal gland are evaginated into the mesoblastic tissue as *sperm tubes*, or sexual cords. By growths of the mesoblastic tissue the sexual cords are divided into roundish, follicle-like masses, which become hollowed out to constitute the *seminal ampullæ*. These, by further growth, are transformed into *seminiferous tubules* (Fig. 2753, No. 6), containing, among many smaller cells, a less number of large *sperm cells* (spermatogones) which develop into spermatozoa. By further transformations the characteristics of the adult testicle proper, or *didymis* (Fig. 2752, *Tunica vag. Vis.*), are developed. At the same time marked changes occur in the *mesonephros*, for from the sexual series of the transverse tubules of this organ cords of cells *penetrate* the germinal glands and fuse with the seminiferous tubules. The conversion of the cell cords into tubes produces the *coni vasculosi* of the *head* or globus major (Fig. 2763, No. 2; Fig. 2754, No.8; Fig. 2762) of the epididymis, which are homologous with the parovarium of the female; the *vasa efferentia* (Fig. 2763, No. 3); the *rete testis* (No. 9); and the *vasa recta* (No. 7). The cephalic part of the Wolffian duct (from the mesonephros, Fig. 2752) develops into the *body* (Fig. 2763, No. 10) and *tail* or globus minor (Fig. 2763, No. 10; Fig. 2754, Nos. 4, 4, 4, 4) of the epididymis, while the caudal portion becomes the *vas deferens* (Fig. 2763, No. 12; Fig. 2754, W.) (homologous with the duct of Gärtner of the female). Near the extreme caudal portion of the Wolffian duct an evaginated pouch appears which develops into the *seminal bladder* (Fig. 2754, *V.*) and its duct. Caudad of this evagination the Wolffian duct becomes the *ejaculatory duct*.

The pronephros degenerates in both sexes into a vestige, *the stalked hydatid*, or hydatid of Morgagni, a little pedunculated sac attached to the upper part of the epididymis in the male (Fig. 2754, No. 7; Fig. 2762). The non-sexual caudal series of mesonephric tubules likewise give rise to a vestigial structure,

the paradidymis (Fig. 2754, Nos. 3, 3, 3), or organ of Giraldès, homologous with the paroöphoron in the female, lying among the convolutions of the tail of the adult epididymis. Primitively the germinal glands were arranged segmentally and extended along a greater number of somites as in Amphioxus at present. Each segment discharged its germ cells into an atrium and thence by an atriopore to the external water where impregnation took place; or, as in the higher Cyclostomes, the spermatozoa were discharged into the celom and made their way through the urogenital pores into the urogenital sinus and thence to the water. Then in Elasmobranchs the advance took place by which the spermatozoa are discharged along the Wolffian duct, a condition which persists in all the higher vertebrates.

In the male the Müllerian duct becomes vestigial throughout nearly its whole extent. Its cephalic extremity persists as the sessile or unstalked hydatid (Fig. 2754, No. 6), and is homologous with the fimbriated extremity of the Fallopian tube in the female. It is a small vesicle attached to the cephalic part of the testicle. The caudal part of the duct becomes the *uterus masculinus* (Fig. 2754, *M.*), and is homologous with the vagina and uterus. Should the intervening part of the duct persist in a patulous condition it is known as the *duct of Rathke* and is homologous with the oviduct of the female.

Testes.—The testes in some Mammals, as in *Manis* among the Edentates, are subintegumental and lie in the inguinal canal. They remain normally in the abdomen in many Mammals, as in Monotremes, most Edentates, and the Elephant.

During ontogeny the testes arise in the same relative position as the ovaries in Mammals. Whereas normally, in man, the ovary never passes further caudad than the pelvis, the testis usually passes out of the abdomen through the *inguinal canal* into an evagination of the abdominal wall (*scrotal sac*) lined by evaginated peritoneum (*tunica vaginalis*). In some of the lower Mammals the two scrotal sacs continue separate, but in man they unite by a median raphe into a single scrotum. In man and most Mammals the testes remain permanently in the scrotum by reason of the great reduction in size of the inguinal canal. Through arrest of development man's testicles may present all degrees of reversion in position to that of more primitive types.

The descent of the testes is a late development peculiar to Mammals. Primitively it was a periodic phenomenon occurring in the adult. At present, in the hedgehog, the testes retain their primitive celomic position up to the rutting period; but as the rut approaches they come to lie in evaginable portions of the abdominal wall in the inguinal region. After the rutting season they return to their abdominal position.

In their descent the testicles necessarily drag after them their attached structures, such as the spermatic artery and veins, the vas deferens, lymphatics, and nerves, all bound together by connective tissue, and thus constituting the *spermatic cord* (Fig. 2762, *Funiculus Sperm*).

Mode of Descent of the Testicle.—The descent of the testicle is a striking feature of its development. From the mode of development of the mesonephros and its ventro-median genital gland, they both are situated behind the peritoneal sac. Increasing in size they invaginate the sac and apparently project into the abdominal cavity, being held in position by peritoneum (mesorchium). Since the mid-kidney is the most conspicuous part of the projecting mass, the portion of the mesorchium extending to the diaphragm is called the *diaphragmatic ligament* (Fig. 2752, *D. L.*) of the kidney and the segment extending to the inguinal region is designated its *inguinal ligament* (Fig. 2752, *I. L.*). When the primitive kidney has become incorporated with the testicle as a part of its excretory apparatus, the inguinal ligament connects exclusively the testicle with the inguinal region. The inguinal ligament contains between its peritoneal folds connective tissue and unstriped muscular fibers, which become the *gubernaculum testis*. It is through processes of unequal growth of the body of the fetus and the tissues of the ligament that the testicle is displaced from the side of the lumbar spine to the false pelvis and thence through the inguinal canal into the scrotum. The most primitive mode of descent is that observed in Insectivores, where it is accomplished through the agency of the cremasteric muscle.

Development of the External Genital Organs.—While the allantois is growing there is formed, near the caudal extremity of the embryo, a *surface depression* extending toward the cloaca. This depression is known as the *anal pit*, or *proctodeum*. The anal pit, though communicating with the surface, is partitioned off from the cloaca by the *anal membrane*. This membrane has its mesoblast crowded aside by the anal epiblast and the cloacal hypoblast growing together. By the breaking down of the anal membrane the cloaca is enlarged and communicates with the surface. Should the membrane fail of normal absorption a child would be born with *imperforate anus*.

In Fishes, Amphibians, Reptiles, Birds, and the lowest Mammals (*Monotremes*), the cloaca is a permanent structure through which the intestinal, urinary, and testicular secretions are voided. Man evolves first to and then beyond the cloacal state. In all mammals above Monotremes, and therefore in man, the *enlarged cloaca* (cloaca-proctodeum) undergoes division about the eighth week into a dorsal or *anorectal* cloaca (rectum and canal of the anus) and a ventral or *urogenital* cloaca (Fig. 2753, *U. of Cl.*, *A. of Cl.*, *U. of P.*, *A. of P.*). This division is accomplished by the growth and fusion of three ridges, one of which appears at the point of union of the gut and the urogenital sinus, while the other two extend, one from each lateral wall of the cloaca. The septum formed by the growth and fusion of the three ridges continues to thicken, especially near the surface, until it forms a pyramidal mass of tissue, called the perineum, or, preferably, the *perineal body* (Fig. 2753, *S.*), since the urogenital portion of the outlet of the pelvis has been designated as the perineum. The urogenital portion of the cloaca-proctodeum develops into the *membranous urethra* of the adult male.

Just ventral to the aperture of the cloaca (cloaca-protodeum), about the sixth week, appears the *genital eminence* (Fig. 2753, *G. E.*, Figs. 2 756and 2757), and soon both cloacal aperture and the eminence are surrounded by the *genital ridges*. About the eighth week a groove (*genital groove*) appears on the under or cloacal surface of the genital eminence in *continuity with* the urogenital cloaca-proctodeum, and therefore with the urogenital sinus (Figs. 2754, 2756, and 2757). The groove becoming deeper is bounded laterally by projecting folds (Figs. 2756 and 2757) of skin (*genital folds*). For descriptive purposes, later, the genital folds may be divided into intra- and extraperineal portions. It is due to the growth of the perineal body that the anus is pushed entirely out of the field of the developed genital ridges (scrotum). The external genital organs of the male represent a further stage of development than the corresponding female parts. The genital eminence early acquires a knob-like extremity which develops into the *glans penis* (homologous with glans clitoridis) and its enveloping *prepuce*. The rest of the genital eminence, exclusive of the genital groove and genital folds, becomes developed into the corpora cavernosa of the clitoris or penis, and their enveloping tissues. The penis has well-marked intra- and extraperineal segments.

In both sexes, by further growth, the genital folds are extended along the sides of the outlet of the urogenital portion of the proctodeum dorsad toward the

perineal body, so that a large part of the groove is caudad from, but continuous with, the outlet of the proctodeum (Fig. 2757). This portion of the genital folds may be spoken of as the *intraperineal* parts. By ventrad extension of the genital eminence and its glans penis, the *extraperineal* parts of the penis are formed. The extraperineal development of the genital eminence in the female is so slight that it scarcely exists—in her the eminence is essentially intraperineal. In the female, through lack of fusion of the segments, the intraperineal parts form the *nymphæ* with their contained *bulbi vestibuli* and *pars intermedia* as the lateral boundaries of the genital groove, the *fourchette* as the dorsal boundary, and the *glans clitoridis* as the ventral boundary of the *genital groove*. The genital groove, caudad from the proctodeum, becomes in the adult the most caudal morphological element of the internymphal cleft (Figs. 2755, 2757). In the male development proceeds further than the stage represented in Fig. 2757. The genital folds bordering the outlet of the proctodeum fuse at their free margins and form the *intraperineal* portions of the corpus spongiosum (bulb and portion of the body), the intraperineal urethra, and the enveloping skin. This intraperineal portion of the corpus spongiosum is homologous with the bulbi vestibuli and pars intermedia of the female. By ventrad extension of the genital eminence and its genital folds and groove, and fusion of the fold margins, the extraperineal (pendulous) portion of the corpus spongiosum and its urethra are formed. The distal opening of the urethra is the *meatus urinarius*. It is generally stated in works on embryology, to the confusion of students of homology, that the urogenital sinus of the sexually undifferentiated embryo is homologous with the prostatic and membranous urethra of the male and with the vestibule of the female. But this certainly is incorrect. It seems to us far more in conformity with the facts

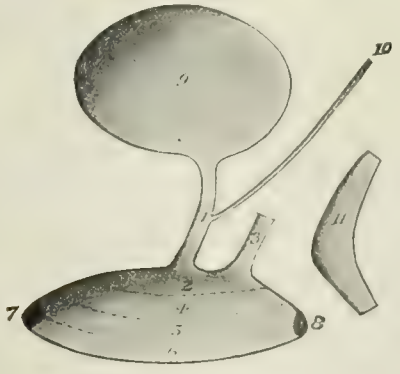

Fig. 2755.—Sagittal Section through the Adult Vulva, Vagina, Urethra, etc. Medial surface. Diagrammatic. 1, Urethra (proximal part of the urogenital sinus); 2, distal part of the urogenital sinus or proximal part of the internymphal cleft; 4, stratum of the internymphal cleft corresponding to the urogenital cloaca; 5, stratum of the cleft corresponding to the urogenital proctodeum; 6, stratum corresponding to the genital groove of the genital eminence; 2, 4, 5, 6, mesial surface of the right boundary of the internymphal cleft; 7, glans clitoridis; 8, fourchette; 9, bladder; 10, duct of Gartner (persistent Wolffian duct); 3, vagina (enlarged Müllerian duct); 11, rectum; 1, 2, 4, 5, 6, urethro-internymphal channel and homologous with the entire male urethra. Compare with Fig. 2754.

to say that the *embryonic urogenital sinus* (Figs. 2753 and 2754, *U. G.*), plus the *urogenital cloaca* (*U. of Cl.*), plus the *urogenital proctodeum* (*U. of P.*), and plus the *genital groove* (*G. E.*, or *C. of G. E.*), differentiate into the *male urethra* from the neck of the bladder to the meatus urinarius on the one hand, or into the *female urethra and internymphal cleft* on the other hand (Fig. 2755). So that the male urethra is homologous with the urethro-internymphal space of the female.

The *vestibule* in human anatomy is described as the space extending from the glans clitoridis to the ostium vaginæ and between the nymphæ. The vestibule as thus defined is useless for studying homologies. The *whole space* between the nymphæ extending from the glans clitoridis (Fig. 2755, No. 7) to the fourchette (Fig. 2755, No. 8) must be considered. This internymphal space of the female is formed from several (four) distinct morphological elements, as follows—viz., a *part* of the urogenital sinus of the embryo (Fig. 2755, No. 2), urogenital cloaca (4), urogenital proctodeum (5), and genital groove (6).

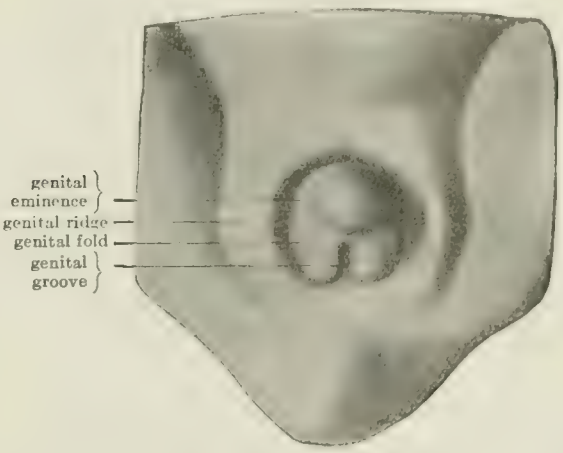

Fig. 2756.—Undifferentiated Stage in the Development of the External Genital Organs. Drawn from Ziegler wax model in United States Army Medical Museum. The genital groove is continuous with the undivided cloaca-proctodeal cavity.

That the most caudal part of the internymphal space corresponds to the spongy urethra is illustrated, among other things, by the fact that the ducts of Bartholin's glands open on the mesial surfaces of the nymphæ external to the hymen, just as the ducts of Cowper's glands open into the spongy urethra. The genital ridge differentiates into the mons veneris, and into two prominent pouches on either side of the penis, which become fused, by a median *raphe*, into the scrotum (homologous with labia majora of female).

By consequence of evaginations from the genital groove there are formed the glands of Cowper (homologous with the glands of Bartholin).

The differentiation of the genital ridges in the female into the *labia majora* enlarges the internymphal space into the interlabial space. In adult human anatomy, the *vulval cleft* usually means the whole interlabial space. From the fact that the external fundiments of the sexual organs are exactly alike in both sexes, it is evident why, through abnormal ontogeny, forms come under observation occasionally which make it very difficult to decide whether they are male or female. These are the so-called cases of *hermaphroditism*. They arise either from the excessive development of certain fundiments or the interrupted development of other parts, in both the male and female. The male is most subject to those malformations which have led to the supposition that there may be hermaphroditism in man. They are due to the fact that the normal processes of fusion are interrupted in association with the interrupted development of other parts. For example, the genital ridges (Fig. 2757) may fail to unite into a scrotum and will simulate the labia majora of the female; the resemblance may be heightened by the failure of the testes to leave the abdominal cavity; and, further, the penis may be so rudimentary as closely to resemble a clitoris. Again, as I have seen, there may be a very noticeable depression between what seem to be incompletely fused

genital folds (Fig. 2757) and every suggestion of a rudimentary *vagina*. The individual, though an adult, may be lacking in a growth of hair on the face; and, lastly, the mammary glands, as I have seen, may be as well developed as a woman's. But in spite of all these misleading features, the presence of *testes* in the abdominal cavity would stamp the individual as a man. In a case of this kind, unless a microscopic examination should reveal a seminal discharge, it would require an autopsy to ascertain whether testes or ovaries were in the abdomen.

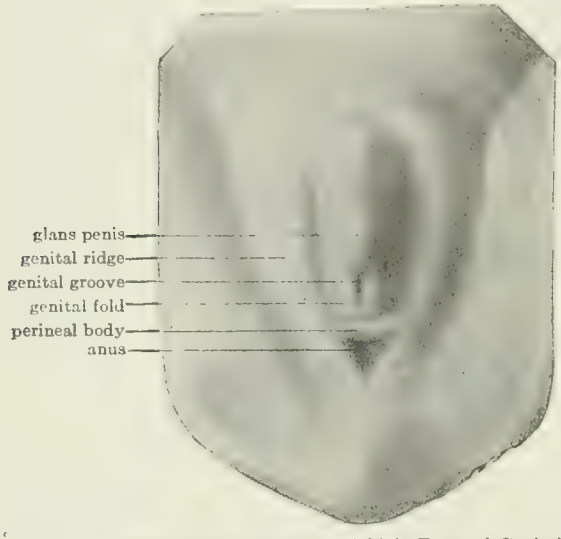

Fig. 2757.—Early Embryonic Stage of Male External Genital Organs. Drawn from Ziegler wax model in United States Army Medical Museum. Genital eminence projects so far dorsad and caudad as to conceal the genital folds and genital groove, which are continued to the under surface of the glans penis. The perineal body has formed and separates the cloaca-proctodeal cavity into a dorsal part having its outlet at the anus, and a ventral part having outlet at the genital groove, in virtue of the fact that the genital folds have extended dorsad and united to form the fourchette just ventrad of the perineal body. It will thus be observed that the genital folds and genital groove are practically divisible, even at this early stage, into intraperineal (root of penis) and extraperineal (pendulous part of penis) segments.

Lack of fusion of the genital folds leads to various degrees of a pathological condition known as *hypospadias*.

Copulatory organs of various forms occur among the vertebrates, often morphologically distinct from one another.

A specially modified portion of each pelvic fin (clasper) occurs in male Sharks. Among the Teleosts the male Girardinus has the terminal portion of the anal fin modified for holding the female, and in many Cyprinoids the anal fin has modifications for a similar function. A marked swelling of the lips of the cloaca occurs in certain Amphibians, as the Urodeles, during the breeding season, by which internal impregnation may take place, but only in male Gymnophiona is a definite copulatory organ present in the form of an eversible cloaca, which is regulated by a well-developed musculature. Among Reptiles two kinds of copulatory organs exist, the one being seen in Crocodiles and Chelonians, and the other in Snakes and Lizards. In the former the organ is single and is a thickened portion of the ventral wall of the cloaca which is regulated by muscles and is protrusible. It consists of erectile tissue and has its dorsal surface grooved for the reception of the seminal fluid from the seminal ducts.

In Snakes and Lizards two copulatory sacs lie under the skin at the root of the tail and outside of the cloaca, which are regulated by a well-developed musculature and can be protruded through the cloacal opening and withdrawn. A spiral groove, for the transmission of semen, extends along each everted sac.

In most Birds the semen is expelled through a non-eversible cloaca, but in many, copulatory organs are present similar to those of Crocodiles and Chelonians.

In the males of all Mammals except the Monotremes, Marsupials, and some Edentates the *penis* consists of two *corpora cavernosa* attached proximally to the *ischia*, and a central portion, the *corpus spongiosum*, perforated by the urethral canal and expanded at the extremity to form the glans. The penis of Monotremes, decidedly reptilian, is situated in the cloaca and is indirectly in relation with the seminal ducts through the urogenital sinus. It consists of an unpaired corpus cavernosum (there is no corpus spongiosum) perforated with a canal in continuity with the urogenital sinus and the seminal ducts. It is only loosely surrounded by the mucous membrane of the cloaca, has a well-developed musculature, and can be protruded through the cloacal aperture.

The penis sheath, in Marsupials, opens directly on the surface of the body ventral to the anus, on account of the growth of the perineum. The two openings are surrounded by a common sphincter muscle. The erectile tissue is paired (two corpora cavernosa), but unconnected with the ischia.

The penis of Insectivores and Rodents, among Placental Mammals, approaches nearest that of Marsupials. In the ascending scale of Mammals the opening of the penis sheath is separated more and more from the anus and the penis comes more and more to a ventral position, attaining a horizontal and fixed position along the abdomen. In the Apes the organ becomes more or less free from the body wall at its distal end, while in Man the whole of the distal end is free and the penis sheath forms a double integumentary tube-like investment (prepuce) over the glans.

During ontogeny, in Marsupials and Placental Mammals, the penis passes through stages that resemble successively those which are permanent in Crocodiles and Monotremes.

Chronology of Urogenital Development.—*Third Week.*—About this time the Wolffian duct and pronephros are recognizable, the nephrotomes begin to develop and also the allantoic stalk appears.

Fifth Week.—The germinal ridges and the Müllerian duct appear and the fetus is two-fifths of an inch (one centimeter) long.

Sixth Week.—The genital eminence, folds, groove, and ridge appear.

Seventh Week.—The mesonephros reaches its maximum development.

Eighth Week.—The caudal portions of the Müllerian ducts fuse, and the allantois presents a spindle-shaped dilatation in its middle forming the bladder.

Ninth Week.—The cloaca is divided into two parts. The permanent kidney has characteristic features. The testes are distinguishable from ovaries. The fundiments of the external genitals begin to show distinctions of sex. The fetus is one inch long (25 millimeters) and weighs about half ounce (16 grams).

Third Month.—Prostate gland begins to develop. The union of the testes with the canals of the Wolffian body is complete. The testes are in the false pelvis. Fetus is $2\frac{3}{4}$ inches long (7 centimeters) and weighs four ounces (125 grams).

Fourth Month.—Sexual distinctions in external genitals are well marked. The genital groove is closed. The scrotum is formed, as also the prepuce. The prostate is well formed. Fetus is 5 inches (13 centimeters) long and weighs $7\frac{3}{4}$ ounces, or 240 grams.

Seventh Month.—The testes are at the internal abdominal ring. Fetus 14 inches (36 centimeters) long and weighs 3 pounds (about 1.5 kilograms).

Eighth Month.—The testes are in the inguinal canal. Fetus 16 inches (41 centimeters) long. Weighs 4 to 5 pounds (about 2 to 2.5 kilograms).

Ninth Month.—The testes are in the scrotum. Fetus 20 inches (50 centimeters) long. Weighs 6 to 7 pounds (about 3 to 3.5 kilograms).

Anatomy.—The *male urethra* is the urogenital canal extending from the bladder to the extremity of the penis (Figs. 2754 and 2758). In the flaccid state it forms a double curve, but when erect it presents a single curve with the concavity ventrad. It is about 7 inches (19 centimeters) in length when flaccid, but during erections greatly elongated. It is divided in a prostatic portion ($1\frac{1}{4}$ inches or 32 millimeters long)

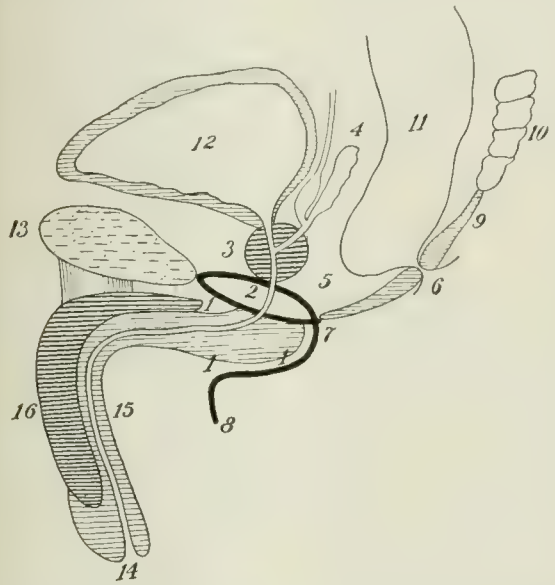

Fig. 2758.—Sagittal Section of Male Urethra. Diagrammatic. 1, 1, 1, Superficial perineal cavity containing the intraperineal segments of the corpora cavernosa, corpus spongiosum, etc.; 2, deep perineal cavity containing the membranous urethra and bounded by the two layers of the deep perineal fascia (triangular ligament of the urethra); 3, prostate gland transmitting the prostatic urethra; 4, vesicula seminalis and vas deferens emptying through the ejaculatory duct into prostatic urethra; 5, site of perineal body; 6, anal portion of rectum (11) passing through the sphincter ani muscle (9); 7, central tendon of perineum whence starts Colles' fascia to continue into the dartos (8) of the scrotum; 10, coccyx; 12, bladder; 13, symphysis pubis; 15, extraperineal portion of corpus spongiosum; the spongy urethra is seen traversing the corpus spongiosum and terminating at the meatus urinarius in the glans penis (14); the bulb of the corpus spongiosum is seen in the superficial perineal cavity, resting against the perineal layer of triangular ligament; the prostate is in the pelvic cavity, resting against the pelvic layer of triangular ligament; 16, extraperineal portion of corpus cavernosum; extending between the symphysis and corpus cavernosum is seen the suspensory ligament of the penis.

membranous part (three-quarters of an inch or 20 millimeters long), and a spongy portion (5 inches or 14 centimeters long). The urethra, except during the passage of urine or semen, has the ventral and dorsal surfaces in contact. The prostatic portion (Fig. 2578, No. 3) is spindle shaped and is the most dilatable and widest part of the canal. A narrow longitudinal ridge (*verumontanum*), three-quarters of an inch (20 millimeters) in length, exists upon the dorsal wall. It is formed by the projecting mucous membrane and contains muscular and erectile tissue. It serves, when distended, to prevent the semen passing back into the bladder. There is a slightly depressed fossa (*prostatic sinus*) on either side of the verumontanum. A depression (*uterus masculinus*) exists at its distal part (Fig. 2754, *M*). It is a *cul-de-sac* about a quarter of an inch (6 millimeters) in length extending dorso-cephalad in the substance of an organ (*prostate gland*), which envelops the prostatic urethra (Fig. 2758, No. 3). Its walls are composed of mucous, connective, and muscular tissue, and the ducts of numerous small glands open upon its mucous surface. The uterus masculinus is homologous with the vagina and uterus of the female. The membranous urethra (Fig. 2758, No. 2) is the narrowest part of the canal except at its termination in the penis. Its ventral surface is concave and is placed about an inch dorso-caudad from the subpubic arch. Its dorsal surface is separated from the rectum by the perineal body (Fig. 2758, No. 5).

The spongy urethra (Fig. 2758, No. 15) is the longest. Its caliber is intermediate between the other segments, and uniform except at either extremity. For half an inch (13 millimeters) behind the terminal opening it is dilated and forms the *fossa navicularis*, while behind, for an inch (25 millimeters), it widens in every direction and is called the *pars bulbosa*.

The urethra is composed of three coats: mucous, areolar, and muscular. The inner, or mucous, coat is continuous at its proximal end with the mucous coat of the bladder and at its distal end with the integument of the penis. It is also continuous with the ducts of the several glands opening into it. Its epithelial lining consists of columnar cells, except at the distal opening, where the cells are squamous. The mucous coat is arranged in longitudinal folds in the membranous and spongy portions when the urethra is empty. The orifices of numerous mucous glands occur on the surface of the mucous coat, especially on the spongy portion, while the glands themselves (glands of Littré) are situated in the submucous connective tissue. The orifices are directed distally and vary in size, and some may easily intercept the point of a small instrument. One of these orifices, much larger than the rest (*lacuna magna*), is situated in the fossa navicularis on its dorsal surface, about half an inch (13 millimeters) or so from the outlet.

The areolar coat is rich in elastic fibers, and its interstices are plentifully supplied with convoluted vessels which serve the purpose of erectile tissue. The outer or muscular coat consists of two layers of unstriped muscular fibers, the outer being longitudinal and the inner circular.

The Perineum and Penis.—The male perineum (Fig. 2759), or urogenital region of the outlet of the pelvis, is bounded by the subpubic arch (Nos. 1, 1), the pubo-ischiatic rami (No. 4), the ischial tuberosities (No. 7), and the transversus perinei muscles. The arch and rami present two lips and an intermediate space. The transversus perinei muscles, one on either side, arise laterally from the ischial tuberosities and are inserted medianly into the central tendinous point (No. 6) of the perineum. Each is innervated by the perineal branch of the internal pudic nerve. Their action is to fix the central tendinous point of the perineum.

Extending from fixed attachments—viz., from the dorsal (posterior) border of the muscles and the central tendon, along their deep (pelvic) surfaces, and thence along the deep (pelvic) lips of the pubo-ischiatic rami, and subpubic arch—is a triangular-shaped fascia (Fig. 2759, No. 5). At the points of attachment the fascia is single, but across the triangular interval which it occupies it divides into two layers, a superficial or perineal layer and a deep or pelvic one. Between the two layers, therefore, exists a space called the *deep perineal cavity* (Fig. 2758, No. 2), which contains a number of structures, viz., the membranous portion of the urethra (whence the name of triangular ligament of urethra for the double-layered fascia), Cowper's glands, the compressor urethræ muscle, subpubic ligament, the internal pudic vessels, the dorsal nerve and vein of the penis, the artery and nerve of the bulb, and a plexus of veins, all bound together by very delicate connective tissue.

The deep or pelvic layer of the triangular ligament is continuous with the pelvic fascia. The superficial layer is the *deep floor* of a second perineal cavity, *the superficial perineal cavity* (Fig. 2758, Nos. 1, 1, 1). The perineum has another important fascia (superficial perineal fascia) which, like the triangular ligament or deep perineal fascia, is divisible into two layers. The deeper layer is the *fascia of Colles*. It is continuous, at the posterior border of the transversus perinei muscles, with the triangular ligament (Fig. 2758, No. 7). It passes superficial to the muscles and is attached firmly to the superficial lips of the pubo-ischiatic rami and the adjacent ischial tuberosities, but is *not attached* to the superficial lip of the subpubic arch, for the corpora cavernosa and the corpus spongiosum intervene (Fig. 2759, Nos. 1, 1). Colles' fascia, in this region, is continuous with the dartos of the scrotum (Fig. 2758, Nos. 7, 8).

This *superficial perineal cavity* is bounded thus on the pelvic side by the triangular ligament (Fig. 2758, No. 2), on the cutaneous side with the fascia of Colles (Nos. 7, 8), laterally by the intermediate surface of each pubo-ischiatic ramus (Fig. 2759, No. 4), and dorsally (posteriorly) by the line of junction of Colles' fascia and the triangular ligament (Fig. 2758, No. 7). The superficial perineal space is continuous ventrally with the *subdartos* space of the scrotum and penis (Fig. 2758, No. 8; Fig. 2759, Nos. 1, 1).

It is in the superficial perineal cavity that extravasation of urine most frequently takes place in cases of rupture of the urethra. From the nature of the fascial attachments, it is clear that the only direction in which the fluid can make its way is ventrad along the scrotum and penis and thence on the ventral part of the abdomen.

This superficial perineal space contains the following *intraperineal* segments of the penis, viz., the crura penis (Fig. 2759, No. 2; Fig. 2758) partly covered by the erector penis muscle, the bulb and part of the body of the corpus spongiosum (Fig. 2758, Nos. 1, 1, 1; Fig. 2759, No. 3) hidden by the accelerator urinæ muscle, the transversus perinei muscles, and the superficial perineal blood-vessels and nerves.

The crura penis (homologous with the crura clitoridis of the female) are the intraperineal and diverging parts of two fibrous cylindrical tubes called the corpora cavernosa. The latter are placed side by side and intimately connected by the septum pectiniforme along the median plane for their anterior (extraperineal) three-fourths (Figs. 2759 and 2760); the posterior (intraperineal) fourth of each corpus cavernosum diverges from its fellow to form a strong tapering fibrous process firmly connected to the pubo-ischiatic ramus. In many mammals (*e.g.* lemurs and apes), a bone, the *os penis*, is developed in the septum between the corpora cavernosa.

The corpus spongiosum, a single, bilaterally symmetrical structure, is composed also of two parts, an intra- and an extraperineal portion.

The intraperineal portion commences between the diverging crura penis, where it forms an enlargement, the *bulb*, and then narrowing forms a part of the body (Fig. 2758, Nos. 1, 1, 1; Fig. 2759, No. 3). The extraperineal part is composed of two segments, the remaining portion of the body (Fig. 2758, No. 15) and the *glans penis* (No. 14). The body is cylindrical and situated in a groove on the ventral surface of the corpora cavernosa (Fig. 2760, No. 10). The glans penis overlaps the rounded extremities of the corpora cavernosa and presents the form of an obtuse cone flattened dorso-ventrally (Fig. 2758, No. 14). At its summit is a vertical opening, the meatus urinarius. The base forms a projecting rounded border (corona), behind which is a constriction (neck). Both these parts have numerous sebaceous glands secreting a cheesy matter of peculiar odor.

The three fibro-elastic tubes (viz., the corpus spongiosum and the corpora cavernosa) enclose a fibrous trabecular structure whose meshes lodge the erectile tissue. The trabeculæ are more delicate and the meshes smaller in the corpus spongiosum. The meshes or areolæ of the corpus spongiosum freely communicate with one another. The areolæ of the corpora cavernosa freely communicate with one another on each side, and also with those of the opposite side through fissures in the fibrous septum between them. The areolæ are lined with epithelial cells and are comparable to widely dilated capillaries. At several points in their walls arteries communicate with them; they give origin to the veins. Blood rushing into, and being retained in the areolæ causes erection of the penis.

The corpus spongiosum and the corpora cavernosa, with their envelopes, constitute the penis. The intraperineal segments of the penis converge at the apex (ventral part) of the superficial perineal cavity and, passing out of the cavity beneath the symphysis pubis (Figs. 2758 and 2759, Nos. 1, 1), form the pendulous body (extraperineal portion) of the penis. A

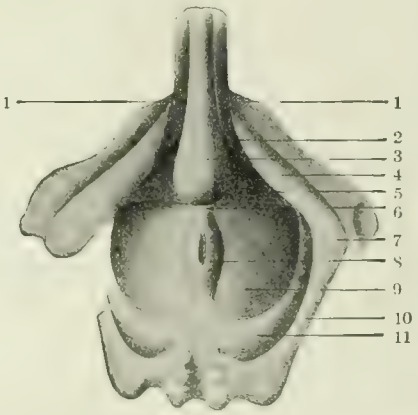

FIG. 2759.—Male Perineum, Showing Triangular Ligament and the Intra- and Extraperineal Portions of the Penis. Colles' fascia and the superjacent parts have been removed. 1, 1, Region of subpubic arch hidden by penis; 4, rami of pubes and ischium (pubo-ischiatic rami); 7, tuberosity of ischium (drawn much too far dorsad); 6, central tendon of the perineum, between which and the tuberosities of the ischium extend the transversus perinei muscles (omitted in the drawing); 5, triangular ligament or deep perineal fascia, on the superficial or perineal layer of which are shown the following structures, viz., 3, the bulb of the corpus spongiosum from which the enveloping accelerator urinæ muscle has been removed; 2, crus penis of the corpus cavernosum, from which on either side the enveloping erector penis muscle has been removed. 8, Sphincter ani; 9, levator ani. The dorsal boundary of the triangular ligament is seen in the figure to extend as far back as the central tendon, where it is continuous with Colles' fascia. The triangular ligament is shown to be attached to the deep or pelvic lip of the pubo-ischiatic rami and subpubic arch; Colles' fascia has been removed from the superficial lip of the rami. The portions of the penis dorsad from the subpubic arch are intraperineal portions, while the parts ventrad of the arch are extraperineal.

strong band of fibrous tissue (the suspensory ligament of the penis) passes downward from the symphysis and blends with the fibrous cylinders of the corpora cavernosa (Fig. 2758).

The urethra (spongy portion) extends throughout the length of the corpus spongiosum and terminates at the meatus urinarius.

The erector penis muscle (homologous with the erector clitoridis) embraces the crus penis and arises from the intermediate space of the pubo-ischiatic ramus and the ischial tuberosity. It is inserted into the sides and ventral surface of the crus. By compressing the crus it assists in causing and maintaining erection. The accelerator urinæ muscle is bilaterally symmetrical. It is also called the ejaculator seminis. It is homologous with the sphincter vaginæ or bulbo-cavernosus of the female. It arises from the central

tendinous point and from the median raphe in front. From these points its fibers diverge like the plumes of a feather. The greater number course around the sides and are inserted into the dorsum of the intraperineal part of the corpus spongiosum, while the foremost fibers extend around the lateral part of each corpus cavernosum and are inserted into the midline of the dorsum of the two bodies, covering the dorsal vessels. By compressing the latter it helps to cause and maintain erection. The superficial layer of the superficial perineal fascia acquires no bony attachments and is continuous with the corresponding fasciæ of the scrotum, thighs, and ischiorectal fossæ.

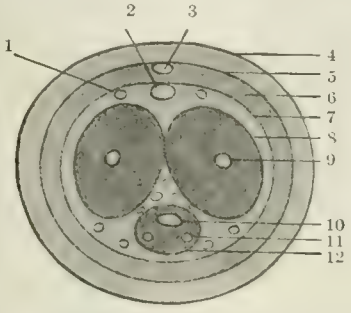

Fig. 2760.—Transverse Section of the Penis. Diagrammatic. 1, Dorsal artery; 2, deep dorsal vein; 3, superficial dorsal vein; 4, skin; 5, dartos (superficial layer of superficial fascia); 6, deep layer (areolar tissue) of the superficial fascia; 7, deep fascia; 8, cylindrical membrane containing erectile tissue of corpus cavernosum; 9, artery of corpus cavernosum; 10, spongy urethra in corpus spongiosum; 11, branch of artery of bulb supplying corpus cavernosum; 12, cylindrical membrane containing erectile tissue of corpus spongiosum; surrounding the latter are several blood-vessels.

The common envelopes of the extraperineal penis are the skin, superficial fascia (containing the dartos), and deep fascia. The dartos is the superficial layer of the superficial fascia and contains unstriped muscular fibers, and is continuous with the dartos of the scrotum. When contracted, it compresses the veins of the penis and favors erection. The skin is remarkably thin, is loosely connected with the deeper parts, is dark in color, and free from adipose tissue.

The erectile structures receive sympathetic nerves from the pelvic plexus and spinal nerves from the superficial perineal and the dorsal nerve of the penis. The coverings of the penis receive nerves from the inferior perineal of the internal pudic and from the genital branch of the genito-crural nerve. They receive *blood* from the external pubic artery, and from the superficial perineal and dorsal artery of the penis, branches of the internal pudic. The bulb and body of the corpus spongiosum are supplied by a branch (artery of the bulb) of the internal pudic. Each corpus cavernosum receives the cavernous branch of the internal pudic. The glans is mostly supplied by the dorsal artery of the penis (Fig. 2760).

The *veins* from the envelopes of the penis converge to the dorsum of the organ and empty into the superficial dorsal vein, lying in the areolar tissue beneath the dartos along the median line and emptying into the obturator and external pudic veins. The veins from the glans emerge at its neck and form the deep dorsal vein which runs in the median groove on the cavernous bodies beneath the deep fascia (Fig. 2760). It perforates the triangular ligament and empties into the prostatic plexus. Those from the body and bulb enter the same plexus or the internal pudic vein. Small veins emerge from the ventral and dorsal surfaces of the corpora cavernosa. They empty into the deep dorsal vein, the former circling around the sides of the bodies. The principal vein comes from the posterior part of each cavernous body, and, perforating the triangular ligament, enters the prostatic plexus.

The superficial lymphatics of the penis empty into the superficial inguinal glands, while the deep lymphatics empty into the pelvic glands about the internal iliac artery.

The Testicle, Spermatic Cord, and their Envelopes.—The testicle is the gland that secretes the male germ cells or spermatozoa (Figs. 2761 and 2762). It is supplied with arteries, veins, lymphatics, nerves, and an excretory duct (vas deferens). In migrating, during development, from the abdomen it evaginates portion of the peritoneum (visceral and parietal layers, which subsequently become pinched off and form the *tunica vaginalis*) and all the layers of the abdominal wall in the inguinal region. It pushes in front of it, hernia-like, the following layers in addition to the peritoneum—viz., first, the *subperitoneal connective tissue*, and then, in order, the *infundibuliform fascia* (portion of transversalis fascia), some of the lower fibers of the internal oblique muscle thus forming the *cremasteric fascia*, the *intercolumnar fascia*, the *dartos* (superficial fascia rich in unstriped muscular fibers,) and, finally, the *skin* (Fig. 2761). The path of the testicle through the abdominal wall is the *inguinal canal;* the evaginated, many-layered pouch is the *scrotal sac*, one on either side. By fusion the skin forms a common covering for both testicles, the line of fusion being indicated by the raphe; but the remaining layers meet in the median plane to form the *septum scroti*. All the envelopes of the two glands together form the *scrotum*. The deep "opening" of

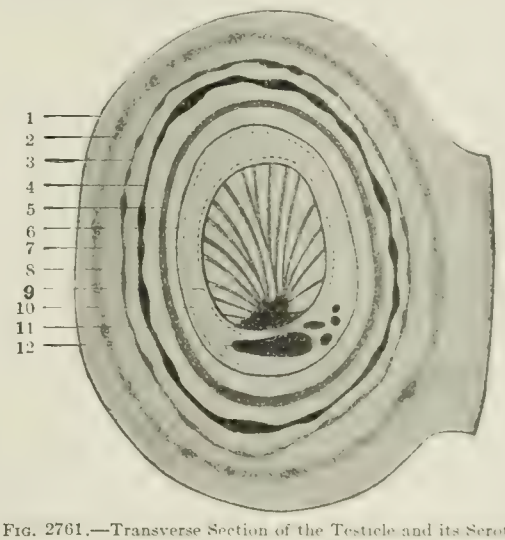

Fig. 2761.—Transverse Section of the Testicle and its Scrotum. Diagrammatic. For the sake of clearness the individual layers of the scrotum are represented as widely separated. 1, Skin; 2, dartos (superficial fascia); 3, intercolumnar fascia; 4, cremasteric fascia; 5, infundibuliform fascia; 6, subperitoneal fascia; 7, parietal layer of the tunica vaginalis; 8, cavity of the tunica vaginalis; 9, visceral layer of the tunica vaginalis connected by subserous areolar tissue to the tunica albuginea (10); 11, the mediastinum giving off trabeculæ to the tunica albuginea; 12, epididymis.

the inguinal canal is the *internal abdominal ring;* the superficial or subcutaneous end is the *external abdominal ring* (Fig. 2754, *Ext. Ab.*).

The inguinal canal is oblique and runs parallel with Poupart's ligament. It is about an inch and a half in length. It commences near the middle of Poupart's ligament and half an inch cephalad from it, and extends to the spine of the pubis. Its cephalic boundary is the arched fibers of the internal oblique and transversalis muscles; its caudal boundary is formed by the union of Poupart's ligament with the transversalis fascia; the ventral boundary is the skin, superficial fascia, aponeurosis of the external oblique, and partly by the internal oblique; the dorsal boundary

is the triangular fascia, the conjoined tendon of the internal oblique and transversalis muscles, the subperitoneal connective tissue, and peritoneum.

The testicle, in migrating from the abdomen into the distal part of the scrotum, carries with it its tributary structures, such as the vas deferens, arteries, veins, lymphatics, and nerves, all bound together with connective tissue into a *spermatic cord* (Fig. 2762). The spermatic cord extends from the testicle to the internal abdominal ring, and is therefore divisible into a scrotal and an inguinal portion.

The Testicles.—Each testicle consists of two separate but closely related parts, viz., the testicle proper, or didymis (Fig. 2762, *Tunica vag. Vis*), and an epididymis (*globus major, globus minor*). Each didymis is compressed laterally and is oval in form. It is one and a half to two inches long (38 to 50 millimeters), an inch and a quarter (30 millimeters) dorsoventrally, and one inch (25 millimeters) in breadth. It weighs about six drams (24 grams). It has a lateral, convex surface looking outward and a little backward; a median, flat surface looking inward and a little forward. The dorsal border, nearly straight, is directed backward and upward and has attached upon its entire length, nearer its lateral than its median part, a structure composed of convoluted tubules and called the *epididymis*. The ventral border of the testicle looks forward and slightly downward. The inferior or caudal extremity is pointed and occupies a plane posterointernal to the more rounded upper or cephalic extremity. The epididymis consists of an enlarged cephalic *head* (*globus major*), a central portion or *body*, and a caudal, pointed *tail* (*globus minor*). The tubules of the globus major are continuous directly with those of the testicle (Fig. 2763, No. 3), but the body and globus minor are connected to the testicle by the tunica vaginalis and its subserous connective tissue. In horizontal section the body resembles a comma, and therefore it shows it to possess a ventral and dorsal surface, as well as lateral and median borders. The dorsal surface is convex, the ventral is concave. Between the concave surface and the testicle is a blind depression (*digital fossa*) opening laterally. The median border corresponds to the tail of the comma.

There are found connected with the globus major and neighboring part of the testicle two small bodies (*hydatids of Morgagni*), one of which is sessile and the other pedunculated (Fig. 2762). The former, one-eighth to one-third of an inch (3 to 8 millimeters) in length, is flattened or rounded, and situated ventrally either on the globus major, the adjacent part of the testicle, or between the two; the latter, about the same size, is attached to the globus major. The hydatids are fetal vestiges.

The testicle proper (didymis), as distinguished from its epididymis, is a fibro-glandular structure (Fig. 2763). The outermost part (*tunica albuginea*) is a dense connective-tissue membrane, which at the dorsal border is reflected ventrally into the gland and forms an incomplete vertical septum (*mediastinum*). From the sides and front of the mediastinum numerous connective-tissue cords and laminæ (*trabeculæ*) radiate to the inner surface of the tunica albuginea. Thus the interior of the gland is divided into a number (about two hundred) of incomplete cone-shaped spaces (*loculi*), which have their bases at the inner surface of the tunica albuginea and their apices at the mediastinum. In the cone-shaped loculi and lining the tunica albuginea and trabeculæ is a vascular layer (*tunica vasculosa*) consisting of a network of minute blood-vessels held together by delicate connective tissue. The true glandular tissue (seminiferous tubules) occupies the loculi. Each loculus contains two or three seminiferous tubules (*tubuli seminiferi*), commencing at the base of the space by blind extremities and taking a very convoluted course to the apex of the loculus. In their course toward the mediastinum they give off two or three blind pouches, and not only make anastomoses with one another, but also with the tubules in adjacent loculi. The tubules of each loculus, near its apex, unite together and form a single, straight, excretory tube (*tubulus rectus*) which enters the mediastinum. The tubules of a single loculus are bound together by a delicate interstitial connective tissue, rich in minute blood-vessels, and make a cone-shaped body (*lobule*) with the apex at the mediastinum. Each little tube in a lobule is about $\frac{1}{120}$ inch ($\frac{1}{5}$ millimeter) in diameter, and when uncoiled its length is increased about thirty times (about 2 feet or 62 centimeters). The tubuli recti, formed as already described at the apices of the lobules, are smaller in diameter than the convoluted tubules of the lobules. They enter the mediastinum and form throughout that structure a network of anastomosing tubules (*rete testis*) of varying diameter, but always larger than the tubuli recti or convoluted tubules of a lobule. They have no proper wall, but are excavations in the mediastinum lined by epithelium of varying character. At the dorsocephalic part of the testicle these channels finally unite to form about twelve tubes (*vasa efferentia*),

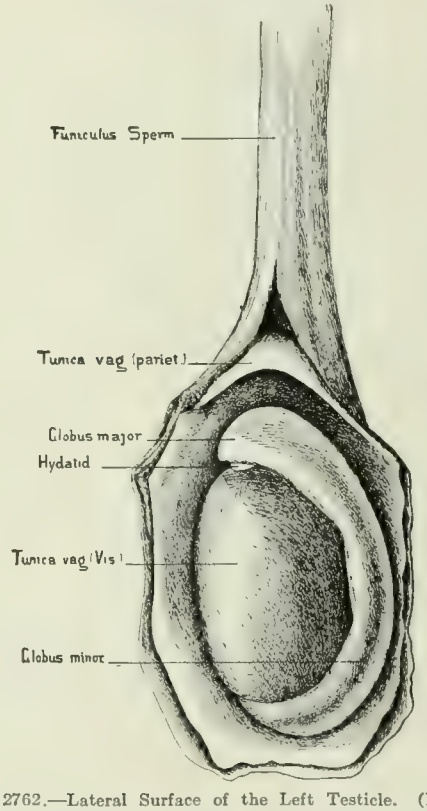

Fig. 2762.—Lateral Surface of the Left Testicle. (Modified from Gegenbaur.) All the layers of the scrotum down to and including the parietal layer of the tunica vaginalis, cut through and turned aside, thus exposing the cavity and the visceral layer of the tunica vaginalis; the latter enveloping the didymis (*Tunica vag. Vis.*), the epididymis (*Globus major, Globus minor*), and the hydatid.

which escape almost immediately through the tunica albuginea and enter into the globus major of the epididymis. The vasa efferentia, shortly after piercing the tunica albuginea, become greatly convoluted and form about twelve cone-shaped bodies (*coni vasculosi*) with their bases turned away from the tunica albuginea. They are each about one-third of an inch (or 8 millimeters) long and enter a common duct and together constitute the globus major. This common duct extends downward, as

the *tube of the epididymis*, and, greatly convoluted, forms the body and globus minor. The coils are held together by connective tissue. The length of the tube when uncoiled is about fifteen feet, or four and one-half meters. Its diameter above is about one-sixtieth inch, or two-fifths millimeter, but gradually decreases toward the globus minor and then enlarges beyond that structure. The tube consists of an inner mucous coat lined with ciliated columnar cells, and an outer coat of unstriped muscular fibers. The tube of the epididymis emerges from the globus minor as a constituent (*vas deferens*) of the spermatic cord (Figs. 2754 and 2763).

Spermatogenesis.—The male germ cells are formed only in the convoluted tubes of the lobules of the testis. The process is homologous with oögenesis (maturation of the ovum) in the female. If a section of a seminiferous tubule be examined, the following arrangement will be observed: Each tubule presents several layers of cells. The layer furthest from the lumen of the tube is formed principally by a number of cells called *spermatogones*. Each of these, from time to time, divides into two daughter cells, one of which persists as a spermatogone, while the other differentiates into a *primary spermatocyte*, thus forming a layer nearer the lumen. This latter cell divides into two cells, the *secondary spermatocytes*, thus forming a layer still nearer the lumen. These undergoing division present a layer of *spermatids*, each one of

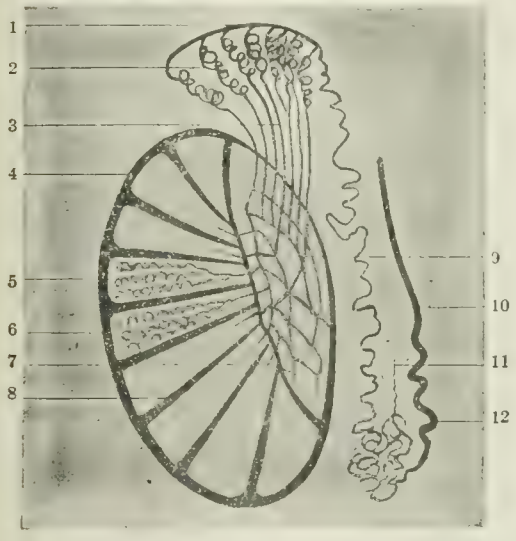

Fig. 2763.—Diagram of Testicular Tubules. 1, Collecting tube of the epididymis; 2, coni vasculosi; 3, vasa efferentia; 1, 2, and 3 form the globus major; 4, tunica albuginea; 5, loculus containing a lobule; 6, lobule; 7, one of the vasa recta; 8, trabecula; 9, rete testis in the mediastinum; 10, tube of the epididymis forming the body and globus minor; 11, vas aberrans; 12, vas deferens.

which develops into a *spermatozoon*. In addition to the preceding cells there are others, found in all the layers, which serve the purposes of supporting and nourishing cells (Sertoli cells). The spermatozoa form the layer of cells next to the lumen. Each spermatid, in differentiating into a spermatozoon, gradually elongates; its nucleus becomes the head of the spermatozoon enveloped by a very thin film of protoplasm; the centrosome lies behind the nucleus in the middle piece or neck; the tail develops behind the neck; an axial filament runs through the neck and tail extending beyond the sheath of the latter as the end-piece. The head is from 2 to 3μ in breadth and from 3 to 5μ in length; the neck is 6μ long and 1μ ($\frac{1}{25000}$ inch) in breadth; the tail is from 40 to 60μ long; the end-piece is 6μ long. In profile view the head is narrow and pointed at its free end, but on surface view it appears oval in shape.

The rate of progression of a spermatozoon is about 0.05 millimeter per second.

Spermatozoa possess remarkable vitality. When mounted on a slide and protected from evaporation they have exhibited motility for nine days. They have been found alive in the male genital tract four days after death. They may retain their activity in the female genital tract for several weeks.

Weak acid solutions kill them.

Structure of the Spermatic Cord.—The *vas deferens* forms the axis of the cord and is about eighteen inches (46 centimeters) in length. It is in the dorsal part of the cord and is recognizable from its cord-like resistance to pressure.

The *spermatic artery* is ventral to the vas, and near the testicle becomes tortuous and divides into several branches, two or three of which accompany the vas and supply the epididymis; others pierce the tunica albuginea and supply the testicle proper (*didymis*). The *deferential artery* is a long, slender vessel accompanying and supplying the vas on its dorsal side and anastomosing with the spermatic near the testis. The *cremasteric artery* courses along the cord supplying the cremasteric and other coverings. Seven or eight *spermatic veins* emerge from the dorsal surface of the testis median to the epididymis, and unite to form the *pampiniform plexus* passing mostly along the ventral plane of the vas and constituting the bulk of the cord. Farther up the cord they are reduced to two or three in number; at the internal abdominal ring they have united into one or two spermatic veins. *Lymphatic vessels* accompany the veins. Plexuses of sympathetic nerves accompany the arteries.

Except for a short distance above the testicle, the scrotal portion of the spermatic cord is lacking in the serous envelope; otherwise the coverings are identical with those of the testis. The inguinal part of the cord has only the following coverings, viz., the subserous connective tissue, the infundibuliform fascia, and cremasteric fascia.

At the internal abdominal ring the constituents of the spermatic cord separate and course in different directions. The vas deferens, after winding around the outer side of the deep epigastric artery, and crossing the external iliac vessels, descends at the side of the bladder into the pelvis. It arches downward and backward to its base, crossing the vestigial hypogastric artery to reach the median side of the ureter. At this point it is sacculated and enlarged, forming the *ampulla*, which extends to the base of the prostate gland (Fig. 2758, No. 3). The ampullæ are median from the vesiculæ seminales, and are between the bladder and the second part of the rectum. They constitute the lateral boundaries of the external trigone of the bladder. At the base of the prostate gland the vas deferens becomes narrowed and, uniting here with the duct from the seminal bladder, forms the *ejaculatory duct* (Fig. 2758). The vas deferens is about two feet (61 centimeters) in length and about a line and a quarter (3 millimeters) in diameter. The spermatic artery can be traced crossing obliquely the external iliac artery and ureter to the aorta a little below the renal artery. It rests on the psoas magnus muscle behind the peritoneum. The right one passes across the inferior vena cava.

On either side two spermatic veins generally accompany each spermatic artery for a distance and then fuse into a single vein. The right one opens obliquely into the inferior vena cava, the left one into the left renal vein at a right angle. The left spermatic veins pass behind the sigmoid colon with their artery. The deferential artery can be traced to the superior vesical artery at the side of the bladder. The cremasteric is a branch of the deep epigastric artery. The lymphatic vessels terminate in the lumbar glands. The

sympathetic nerves are the spermatic plexus derived mostly from the renal, but partly from the aortic plexus. The plexus is re-enforced through the deferential from the pelvic plexus.

Dorsal to the spermatic cord is the internal branch of the genito-crural nerve from the lumbar plexus. It innervates the cremaster muscle. The ilio-inguinal nerve from the lumbar plexus enters the inguinal canal at varying points and appears at the external abdominal ring ventral to the cord. It gives sensibility to the scrotum.

Tunica Vaginalis (Fig. 2762).—As already stated, the tunica vaginalis is the innermost of the scrotal coats of the testis, derived from the peritoneum during the descent of the testis. At birth the cavity of the tunica is directly continuous with that of the peritoneum, so that the tunica consists of inguinal, scrotal, and testicular segments. But, usually, a short time after birth, the inguinal and upper scrotal parts are reduced to a fibrocellular thread lying in the loose connective tissue around the spermatic cord; so that the tunica vaginalis is reduced to a testicular portion. There are all grades of variation between a tunica vaginalis whose cavity is freely continuous with the cavity of the abdominal peritoneum and one whose cavity is absolutely shut off from that of the abdomen, and without even the presence of a vestigial connective-tissue thread.

The *visceral layer* of the tunica is closely adherent to the testicle proper, and to the globus major and lateral part of the body of the epididymus, and is prolonged upward upon the spermatic cord for half an inch (12 millimeters). It extends into the digital fossa between the epididymis and testicle. It leaves uncovered nearly all the posterointernal part of the body and the globus minor of the epididymis. It is in those uncovered parts that extensive vascular communication is established between the testicle and its coverings and the cord. The *parietal layer* is continuous with the visceral layer at the point of reflection from the spermatic cord, and at the posteroinferior parts of the testicle. It is loosely connected with the infundibuliform fascia by the subserous connective tissue. The two layers are in contact normally except for a very thin film of serous fluid secreted by the endothelial cells of the tunica.

The Seminal Vesicles (Fig. 2758, No. 4).—These reservoirs for the semen, to which they add their own secretion, are situated between the bladder and the rectum. They are lobulated pouches of pyramidal shape placed one on either side external to the ampullæ of the vasa deferentia, and are two inches (50 millimeters) long and a half-inch (12 millimeters) wide at the base. They present rectal and bladder surfaces, median and lateral borders, a base and an apex. The ventral surface is attached to the base of the bladder overlapping the ureter. The rectal surface is covered above by the recto-vesical pouch of the peritoneum, but below is separated from the rectum only by the recto-vesical fascia. The bases are widely separated, but the apices converge and narrowing into straight ducts unite, near the base of the prostate gland, with the corresponding vasa deferentia to form the ejaculatory ducts.

Each vesicle consists of a single tube coiled upon itself and giving off many blind diverticula, all bound together firmly by fibrous tissue. When uncoiled the main tube is about five inches (125 millimeters) in length and of the diameter of a quill.

Each ejaculatory duct is about three-quarters of an inch (19 millimeters) long, and commencing at the base of the prostate it runs downward and forward between the lateral and middle lobes to empty into the urethra, near or through the uterus masculinus. The seminal vesicles and ejaculatory ducts have three coats: an inner or mucous one, a middle or muscular one, and an outer or areolar one.

The nerves of the vesicles and ducts are derived from the pelvic plexus. The middle hemorrhoidal and the vesical arteries supply the vesicles and the extraprostatic portion of the duct. The intraprostatic portion receives its nutriment from the prostatic vessels. Veins and lymphatics accompany the arteries, emptying into the vesicoprostatic plexus.

Prostate Gland (Fig. 2758, No. 3).—The prostate is a musculo-glandular body surrounding the proximal urethra and the neck of the bladder. It is in the pelvic cavity behind the lower part of the symphysis pubis. It is cephalad from the deep layer of the triangular ligament of the urethra (deep perineal fascia). It is about the shape and size of a large chestnut. It develops at puberty and atrophies after castration. It presents a base, an apex, a ventral, a dorsal, and two lateral surfaces. The base is situated immediately below the bladder; the apex rests upon the pelvic side of the triangular ligament; the dorsal surface rests on the rectum, distant about one inch and a half (37 millimeters) from the anus; the ventral surface, about three-quarters of an inch (19 millimeters) behind the symphysis, has some loose fat and a plexus of veins in front of it, and is connected on either side to the pubic bone by the puboprostatic ligaments; the lateral surfaces are in relation with the anterior portions of the levator ani muscles, the vesicoprostatic plexus of veins intervening. The prostate consists of a median and two lateral lobes. The lateral lobes are separated by a deep notch at the base and by a slight furrow on the ventral and dorsal surfaces. The middle lobe, variable in shape, is a small transverse band, placed between the two lobes at the posterior part of the gland, behind the proximal urethra. The ejaculatory ducts pass between the middle and lateral lobes. The prostate is enveloped by a thin but firm fibrous capsule continuous with the pelvic layer of the triangular ligament and the rectovesical fascia. It consists of stroma (mostly muscular) and glandular tissue. Immediately beneath the fibrous capsule is a thick muscular layer, and around the prostatic urethra is another strong, circular, muscular layer; extending between the two are a series of decussating muscular trabeculæ, forming interstices that contain the glandular tissue. The tubular glands are arranged around the urethra in a radiating manner, and their ducts (about thirty in number) communicate by minute orifices with the prostatic sinus on either side. They are lined with columnar epithelium and secrete a milky fluid, which is added to the seminal fluid at the moment of ejaculation.

The prostate is supplied by the internal pudic, vesical, and hemorrhoidal arteries. The veins empty into the vesico-prostatic plexus surrounding the organ, and thence into the internal iliac vein. The nerves are derived from the pelvic plexus.

Cowper's Glands.—These glands are two firm lobulated bodies about the size of peas and situated, one on either side of the membranous urethra, between the two layers of the triangular ligament (Fig. 2758, No. 2). They lie close above the bulb among the fibers of the compressor urethræ muscle. Each body is a compound racemose gland, and its duct, lined by columnar epithelium, pierces the perineal layer of the triangular ligament and runs forward for about an inch (25 millimeters) under the mucous membrane, finally emptying into the spongy urethra. The viscid, albuminoid, transparent secretion of these glands is mixed with the seminal fluid at the moment of ejaculation.

DANIEL KERFOOT SHUTE.

Gentiana.—GENTIAN. "The dried rhizome and root of *Gentiana lutea* L. (fam. *Gentianaceæ*)," U. S. P. This, the yellow gentian, is one of the largest and showiest species of the genus. It is a tall, sturdy, mountain perennial, arising from a thick, fleshy, slightly branching or simple, and sometimes very long (from half a meter to one meter or more), yellowish-brown root, and

is a yard or more high. It grows abundantly in the elevated and mountainous parts of Southern and Middle Europe, Asia Minor, etc. In Switzerland, Southern France, and the hilly parts of Germany, it is collected for use. Although sometimes cultivated for ornament, it does not thrive well, and rarely flowers except in its native pastures.

Description.—In cylindraceous, usually slightly flattened, curved or crooked pieces of indefinite length, and from 0.5 to 3.5 centimeters (¼ to nearly 1½ in.) thick, or in longitudinal slices of the same thickness; externally yellowish brown to dark-brown, strongly and crookedly longitudinally wrinkled, and marked with lighter-colored circular root scars, the rhizome finely or heavily annulate; somewhat tough and flexible when damp, rather brittle when dry, the fracture short but uneven, the bark thick, reddish-brown, separated by a dark brown line from the yellowish or reddish-yellow inner portion; free from starch; odor strong, characteristic; taste very bitter, slightly sweetish. The roots of other species are distinguished by their smaller size and tendency to divide into numerous branches at the top. Their introduction is to be regarded as only technically an adulteration, as their properties are identical with those of the official root.

Composition.—The principal constituent of this and other gentians is the peculiar, intensely bitter, crystalline glucoside, *gentiopicrin*, which is soluble in water and diluted alcohol, but not in ether and by means of diluted acids is separated into sugar and *gentiogenin*, a yellow, bitter, neutral powder. The yield is about one and two-third *per mille*. *Gentisic acid* is more abundant. It is in large needle-shaped crystals, tasteless, and almost insoluble in water and ether, but slightly soluble in alcohol. It is not an active substance. The root also contains a good deal of pectic matters, sugar (gentianose), etc., but no starch, and probably no tannic acid, unless the gentisic acid be considered a form of tannin.

Action and Use.—Gentian is the most perfect type at our command of the class of medicines called "simple bitters." In the purity of its bitter taste, the promptness of its action upon the assimilating organs, and the absence of other qualities even in considerably larger than medicinal doses, it has no equal. Gentian is non-toxic, but in excessive amount disturbs the stomach and bowels, and may occasion nausea and vomiting. Sometimes it appears to be slightly laxative. Gentian is employed in medicine almost exclusively for the purpose of obtaining its stimulating effect upon the appetite, gastric secretion, and assimilating functions. Under its influence the appetite improves, the feeling of weight or discomfort felt in the stomach or bowels after eating—if due to debility of those organs—disappears, more food is taken, and probably more of what is taken is assimilated. It must be borne in mind that it probably, like other bitters, has a slight inhibitory action upon the digestive process by its presence in the mass of food. The secondary effect—viz., the improved nutrition of all the organs, and their consequently better performance of their various functions—is what is known as a tonic effect. Strength, weight, color, firmness of tissue, are all improved, and better health results. This drug is, then, indicated in debility, with poor appetite, of a more or less chronic character. It is often of service in dyspepsia, and, in combination with iron, in simple anemia. As an antiperiodic it has been completely superseded by quinine; as a substitute for tobacco and opium in the treatment of those habits it has no special value.

Administration.—Gentian, in the form of the whole root, is sometimes chewed, and the salivary extract swallowed; the method, although troublesome, is an excellent one. The dose is not particularly important, but 2 or 3 grams will probably do as much good as a larger quantity. There are several widely used preparations, all good. Those official in the U. S. P. are the extract, dose gr. iv. (0.25); the fluidextract dose ♏ xv. (1.0); the compound tincture, of 10 per cent. strength, with 4 per cent. of bitter orange peel and 1 per cent. of cardamom, dose fl ʒ i. (4.0). The 20 per cent. tincture, though no longer official, is much used in doses of ♏ xxx.–lx. (2.0–4.0). H. H. Rusby.

Gentianaceæ.—(*The Gentian Family.*) The great size and wide distribution of this family, and the singular uniformity of its species in agreeing with the general composition and properties of the drug last discussed, render it of great importance that army surgeons and travellers generally should be able to recognize them when seen. There are no poisonous plants among them. A very few are slightly or not at all bitter and their roots or leaves are edible. Several *Coutoubeas* are used as anthelmintics. With these exceptions, all the others in use, to the number of a hundred or more, have the properties of the official *Gentian* and *Chiretta*. Among these are a large number in the genera *Gentiana, Swertia, Lisianthus, Pleurogyne, Erythræa* (the "Centaurys"), *Sabbatia, Axacum*, etc. All show a distinct tendency toward laxative properties, and in some this tendency is marked. The family contains upward of sixty genera and nearly a thousand species, Gentiana being the largest genus, with about three hundred species. The family is represented mostly in the temperate zones and in tropical mountains with a temperate climate. They may be known by the following family characteristics: They are mostly herbs, smooth, with opposite, entire, exstipulate leaves, these usually nerved or ribbed. The flowers are solitary or cymose in the axils, or at the summit, the cymes often panicled. The flowers are regular, rarely a little oblique, perfect, 4–5-merous, the corolla gamopetalous. The stamens are of the same number as the corolla lobes, alternate with them and affixed to the corolla tube or throat. The disc, if any, is inconspicuous. The ovary is superior, one-celled, or rarely two-celled by the union of the two parietal placentæ. The ovules are numerous, anatropous or amphitropous. The fruit is usually a two-valved, dehiscent capsule, rarely indehiscent, still more rarely fleshy. The embryo is small, in copious albumen, the radicle, if its direction is distinct, ascending. H. H. Rusby.

Geoform, also known as *guaiaform*, is methylene-diguaiacol. It occurs as a yellow powder, with an odor of vanilla and without taste. It is soluble in alcohol and ether, and insoluble in water. It has been used in cases of pulmonary tuberculosis in doses of 5 to 10 grains, administered in capsules or as powders.
R. J. E. Scott.

Geography, Medical.—The geographical distribution of disease has received the attention of a host of medical observers in all ages, and the statistical data published are overwhelmingly numerous and detailed. Generalizations are almost impossible, for the student is like the man who cannot see the woods for the trees. Nevertheless, little by little, as new medical discoveries are published from the clinic or laboratory, it is found that the distribution of many a disease might have supplied the key to solve the puzzle of etiology long before the pathologists had undertaken their laborious investigations. For instance, a map showing by proper shadings the endemic areas of yellow fever and the areas to which it occasionally spread in summer, should have caused the instant acceptance of Finlay's other facts showing a relation of the disease to a particular mosquito.

There would then have been a demand for a map showing the geographical distribution of each species of mosquito and it would soon have been proved that the disease never appeared except where Finlay's mosquito abounded. The possibility of the carriage of yellow fever by mosquitos had been suggested many times since Finlay's first announcement, and the absence of proper maps was the only reason the ideas bore no fruit and we lost twenty years of life saving. That is, the statistics already existing in abundance are worthless unless they are sorted out and put into graphic form which gives the situation at a glance.

This is being done by the epidemiologists for all those diseases which occasionally run like wildfire through a nation and from country to country, like plague or cholera. This much of medical geography is then found in works on epidemic diseases.

Demography, or the description of the changes in a population as a whole, has absorbed a large part of medical geography. The death rates of the special diseases which reduce a population must be studied from year to year, and compared with the same diseases in all other nations. Unfortunately national boundaries are not parallel with the boundaries of disease areas, and certain diseases prevail in different proportions within a state or nation. Demographers are therefore making maps showing by proper shadings the relative morbidity for each disease in each district. Comparisons of these maps are showing similarities and coincidences which are bound to result in valuable generalizations beneficial to public health.

The statisticians of all health departments, municipal, county, provincial, state, or national, should be provided with funds sufficient to prepare maps showing the detailed prevalence of each of the main diseases within their respective statistical limits. These maps should be of uniform size and shading for ease in comparison, and, moreover, the surface contour lines should be inserted in appropriate number to show the relation to altitude. Medical climatology uses all the facts collected by medical geographers, but correlates them to the various factors which make up a climate—elevation, air moisture and precipitation, heat and its fluctuations by day and season, light, proximity to lakes and seas, and so on. That is, both climatology and medical geography are really statistical store-houses, for the collection and storage of data having no immediate or even no known use, but which can be instantly drawn upon by medical climatologists in their investigations of the diseases caused by adverse climatic factors.

The new science of medical ethnology is making use of the facts collected by the geographers and climatologists as well as the facts as to the geographic distribution of races of men. In this case the "characters" of each human type are first correlated to the environmental factors, geological and climatological, then to the prevailing diseases or lack of diseases, and finally to the special diseases of alien types which have recently immigrated and mingled with the natives who, by selection in a long residence, have become physically adjusted to the environment.

Medical anthropology is also making some use of the geographical distribution of disease in explaining the differences between the morbidity rates in man and the lower animals. Man's evolution has been so rapid, that he has not yet divested himself of all the characters fit for a lower existence, and though these "disharmonies" may not be as numerous or serious as Metchnikoff thinks, they deserve serious consideration in explaining the distribution of disease. In time, of course, we become immune to old diseases of animals with which we come in daily contact, but there are some infections like rabies and anthrax which seem to be new and fatal to the domestic stocks we have created from wild species. The geographical distribution of such diseases in both man and animals might lead to the discovery of immune or tolerant wild species which account for the persistence of these infections.

Medical geography is then purely statistical, but it furnishes material to many subsidiary sciences of great practical value to hygiene and sanitation. The aim and end of all vital statistics should be the preparation of shaded and contoured maps showing the distribution of every disease afflicting man and the lower animals. In time these will be compared with climatological, zoological, and ethnologic maps, with a view to etiological discoveries. For instance, Sambon has found that pellagra in Europe is contracted only along water courses where the simulium or black fly breeds. The germ is apparently carried by this biting fly from some aquatic animal to which it is harmless. The geographical distribution of beriberi is mostly within twenty degrees of the equator and leprosy within forty degrees with a few exceptions such as Scandinavia, and moreover leprosy seems correlated with water courses and seashores with a few exceptions. Some one will probably find a reason for the apparent exceptions and will then correlate the two diseases with the source of their real causes. Both beriberi and scurvy have long been considered purely dietetic, but the latter has now been found to be parasitic and so may the former, and leprosy may be a disease of some water animal and transmitted by an insect.

The census bureau has the machinery and trained personnel for the preparation of medical maps and the collection of the necessary data. At present it mostly relies upon vital statistics from the registration area. It should be given the necessary funds. Unfortunately the people who hold the purse strings have no idea of the incalculable practical value of dry vital statistics, and until a campaign of education carried on by the medical profession enlightens the public, medical geography cannot be as accurate and complete as it should be. In these matters, Europe is far ahead of us and the death rates there are consequently far less than the American, except in the larger cities. We are about where Germany was a quarter of a century ago, and we cannot fight disease until we know where it is and how much there is of it, nor can we find the causes.

CHARLES E. WOODRUFF.

Geophilus.—A genus of myriapods, or centipeds. Three species have been found as accidental parasites in the nasal cavities in man in Europe. *G. electricus* has also been known to occur in the alimentary canal. See *Insects, parasitic.* A. S. P.

Geranium.—CRANESBILL. *Wild Geranium.* "The dried rhizome of *Geranium maculatum* L. (fam. *Geraniaceæ*," U. S. P. This plant is exceedingly abundant in woodlands about New York, and elsewhere in eastern and central North America, and is represented farther west by other species, with similar properties. It is a perennial slender herb, a foot or two high, with palmately lobed, roundish leaves, from two to six inches in diameter, and numerous lilac-purple flowers, something over an inch in breadth. The rhizome is of horizontal growth, 5 to 10 centimeters (2 to 4 in.) long and 0.5 to 1.5 centimeters ($\frac{1}{5}$ to $\frac{3}{5}$ in.) thick, more or less crooked, cylindraceous but somewhat vertically flattened, brown; roughly and shortly wrinkled and strongly, rather sharply tuberculate; fracture short, purple, the bark thin, a few short and broad yellowish wood-wedges scattered near the dark cambium; inodorous; taste strongly astringent.

Besides inert *mucilage, resin, coloring matters,* etc.,

geranium contains from ten to twenty-five per cent. or more of tannin, to which its medicinal value is owing. It is a mild, rather pleasant, vegetable astringent, and considerably employed in diarrhea, chronic dysentery, etc., and as a wash, gargle, or injection, in catarrhs of the pharynx, vagina, or urethra. A fluid extract is official and represents it well for internal use. Dose, ♏ xv. ad xxx. (1.0–2.0). For washes and gargles a ten per cent. decoction may be made in the usual way. Cranesbill is often selected, when an astringent is needed for a child, on account of its comparatively easy administration. HENRY H. RUSBY.

Gerhardt, Carl Adolf Jakob Christian.—Born at Speyer, Germany on May 5, 1833. He received the degree of Doctor of Medicine from the University of Würzburg in 1856. In 1885 he was called by the University of Berlin to fill the chair previously held by Frerichs. He died in 1903.

FIG. 2764.—C. A. J. C. Gerhardt.

Of his published writings the following call for special mention: "Der Kehlkopfscroup," Tübingen, 1859; "Lehrbuch der Auscultation und Percussion," Tübingen, 1890 (5th edition); "Lehrbuch der Kinderkrankheiten," Tübingen, 1898 (5th edition); and "Die syphilitischen Erkrankungen des Kehlkopfs und der Luftröhre," Vienna, 1898. A. H. B.

von Gerlach, Joseph.—One of the most distinguished German anatomists of the second half of the nineteenth century. Born at Mainz, April 3, 1820. He studied medicine at Würzburg, Munich, and Berlin, and graduated at the University of the former city in 1841. He spent the following two years in visiting the hospitals and clinics of Vienna, Paris, and London. Upon his return to his native city in 1843 he began the practice of medicine, and devoted himself partly to this and partly to a very thorough course of anatomical and histological studies up to the year 1848, when he published his well-known treatise entitled: "Handbuch der allgemeinen und speciellen Gewebelehre." In 1850 he was called to fill the regular chair of anatomy at the University of Erlangen. He retained his connection with this institution up to the time of his death in 1896.

Gerlach deserves special credit for his discovery (in 1847) of a method of filling the capillary blood-vessels with a translucent mass of gelatin stained with ammonio-carmine, and also for having introduced (in 1855) other methods of utilizing colored preparations in histological technique. In addition to the Handbuch already mentioned Gerlach has published several works of decided merit—as, for example, "Mikroskopische Studien," Erlangen, 1852; "Das Verhältniss der Nerven zu den willkürlichen Muskeln der Wirbelthiere." Leipzig, 1874; and "Beiträge zur normalen Anat. des Menschl. Auges," Leipzig, 1880. A. H. B.

Germ Cells.—In all animals, except the Protozoa, the cells of the body may be divided into two kinds: somatic cells and germ cells.

The *germ cells* are those which have for their purpose the provision of the material out of which future generations are to be produced. They form but a small portion of the body of any multicellular organism. The greater part of the body is made up of *somatic cells*, which serve to shelter and nourish the germ cells.

The Germinal Cycle.—The complete history of the germ cells has not yet been followed through all its stages in any animal or plant. But enough is known to make it clear that there is a complete continuity of generations of cells in this history, which consists of a series of cycles, and we may consider each cycle as having its beginning and its end in the act of fertilization. These cycles follow one another in unending sequence so long as the race remains extant.

The history of the somatic cells is likewise a series of cycles having their beginnings in the act of fertilization. But there is no continuity between the cycles. For the somatic cells, having fulfilled the purpose of their being, die, and have no genetic relation to the cells forming the body of the next generation, except community of origin in the ancestral germ cells.

In the history of the germ cells each cycle may be divided into several periods, and the cells in each period have been given distinctive names. We shall follow in the main the terminology adopted by Waldeyer (1902).

FIRST PERIOD.—By the union of an ovum and a spermatozoon there is formed a single cell with a nucleus of double origin (see *Impregnation*). This cell is the fertilized egg, or *oöspermium*. Immediately after fertilization there follows a series of cell divisions resulting in what is known as the segmentation of the ovum (see article *Segmentation of the Ovum*).

The series of cells which, beginning with the fertilized ovum, ultimately give rise to germ cells has been called by Weismann the *germ track*. In a few animals it has been possible to trace the differetniation of somatic cells from cells of the germ track back to the first cleavage of the ovum.

In the Diptera (flies) for example the cleavage of the egg (Fig. 2765) begins with the division of the nucleus, which takes place several times before the cytoplasm divides. One of the nuclei moves to one pole of the egg and there becomes surrounded by cytoplasm with different staining reactions from the rest. This nucleus gives rise to the nuclei of all the germ cells of the embryo and to them only, while the others, give rise to the nuclei of all the somatic cells.

A remarkable case of continuity of germ cells has been discovered by Boveri in Ascaris. Figs. 2767 to 2773 represent some of the principal stages illustrated in his beautiful memoir.

The result of the first division is the formation of two cells—the first primary somatic cell and the first stem cell, or *protogonocyte* (S_1 and P_1, Fig. 2766). The latter divides again to form a second primary somatic cell and the second protogonocyte (S_2 and P_2). This series of divisions continues through a number of generations of cells, until finally the last protogonocyte gives rise to a primary somatic cell and the primary germ cell or *archigonocyte* (S_3 and G, Fig. 2766). In the mean time, of course, the somatic cells have been dividing to form the tissues of the embryo.

Fig. 2767 shows the egg in the two-cell stage and both cells, S_1 and P_1, which are apparently alike, are preparing to divide. In Fig. 2768 the division

is farther advanced, and a striking difference is noticeable in the mitotic figures. The chromosomes of the cells *A* and *B*, daughter cells of S_1, are numerous and very small, and in the plane of division there are

Fig. 2765.—Early Stages in the Development of the Parthenogenetic Egg of the Gall-fly, Cecidomyia. *p.z*, Primary germ cell; *c.l*, nutrient cells degenerating. (After Metchnikoff.)

some dark bodies composed of chromatin, the rejected ends of the chromosomes of S_1. These will take no further part in the formation of the nucleus and will finally disappear. On the other hand in P_1,

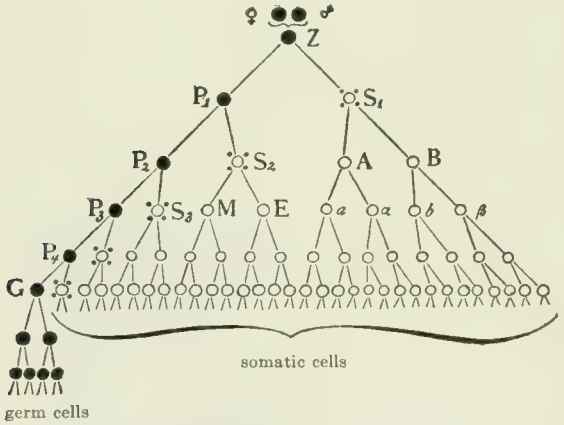

Fig. 2766.—Diagram showing the Pedigree of the Germ Cells of Ascaris. *Z*, Fertilized egg; P_1, P_2, etc., protogonocytes; *G*, primordial germ cell (P_5, Fig. 2772); S_1, S_2, etc., primary somatic cells; *A* and *B*, primary ectodermal cells; *E*, primary endodermal cell; *M*, cell which produces mesoderm and part of ectoderm. (Modified from Boveri.)

which we may call the first cell of the *germ track*, there are only two large chromosomes moving toward each pole to form the daughter nuclei. *A* and *B* are purely somatic cells. Of the daughter cells of P_1, one is likewise a purely somatic cell, and when it divides the chromosomes undergo the same transformation that has been observed in S_1. The other daughter cell is P_2, the second cell of the germ track. This is seen preparing for division in the dorsal view of the six-cell stage, Fig. 2769. The two large chromosomes have been reformed. This cell behaves exactly as P_1 did, giving rise to a somatic cell and to the third cell of the germ track, P_3, Fig. 2770. This cell divides again in the same manner, producing *D* and P_4, Fig. 2771, and one of the daughter cells of P_4 is P_5, Fig. 2772, which in turn produces the two priordial germ cells *UGI* and *UGII*, Fig. 2773. Thus the remarkable difference between the nuclei of the germ cells and the somatic cells in this form has

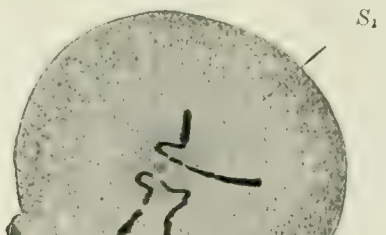

Fig. 2767.—Two-cell Stage of *Ascaris megalocephala* var. *univalens*. S_1, First somatic cell; P_1, first cell of the germ track. Highly magnified. (After Boveri.)

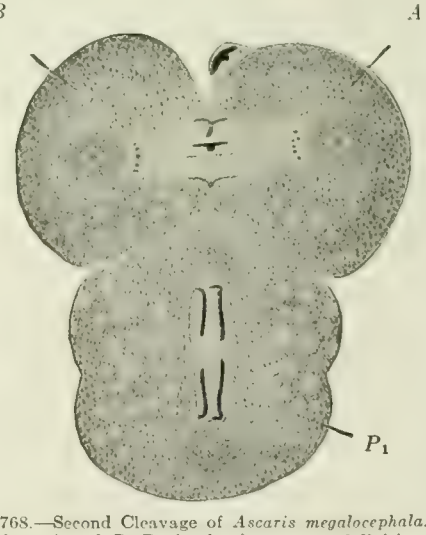

Fig. 2768.—Second Cleavage of *Ascaris megalocephala*. S_1 is dividing into *A* and *B*; P_1, is also in process of division. Note difference in size and number of chromosomes. (After Boveri.)

enabled Boveri to trace every stage in the genealogy of the germ cells and their nuclei back to the fertilized egg.

In most animals, however, the cells which arise by the cleavage of the ovum appear to be somatic cells, some of which after a greater or less number of divisions give rise to germ cells. In the plants and

plant-like animals, such as the Hydroids, we have extreme cases in which there is no trace of recognizable germ cells until we reach the end of a series of several generations of asexually produced individuals.

Second Period.—The second period begins with the division of the primary germ cell, or archigonocyte, to form two *gonocytes* (Fig. 2766 *G*, Fig. 2772 P_5, and Fig. 2773 *UG*). These continue to multiply by division until, according to Beard, they reach a

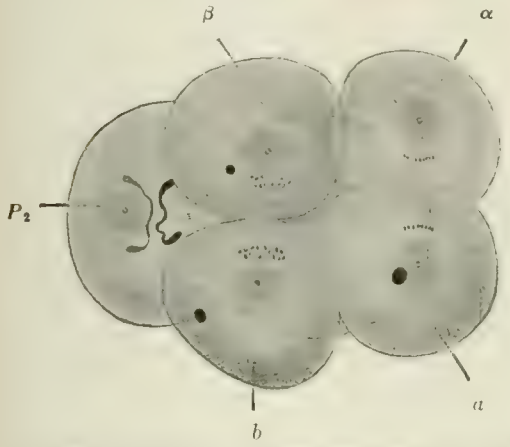

Fig. 2769.—Six-cell Stage of *Ascaris megalocephala*. P_2, Second cell of germ track. *b*, *β*, Daughter cells of *B*; *a*, *α*, daughter cells of *A*, Fig. 2768. (After Boveri.)

certain number, which may be approximately constant for the species.

Our knowledge of the history of the germ cells of vertebrates begins at a fairly advanced stage in the second period. The rudiments of the gonads in vertebrates consist of a pair of *genital ridges* which project into the body cavity, one on each side of the radix mesenterii, lying longitudinally between it and the Wolffian body. The epithelium which covers

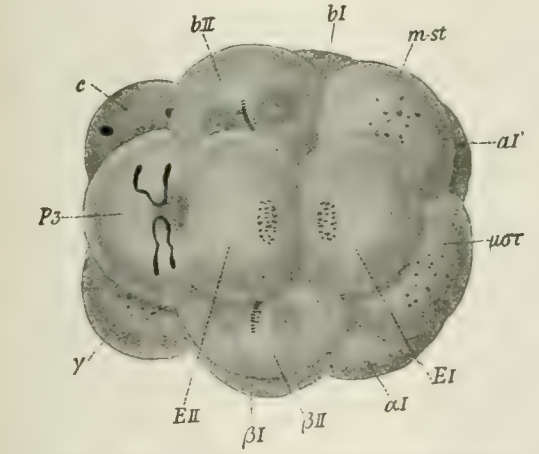

Fig. 2770.—Fifteen-cell Stage of *Ascaris megalocephala*. P_3, Third cell of germ track. (After Boveri.)

the genital ridges differs from the cœlomic epithelium, with which it is continuous, by being usually cuboidal. It is known as the *germinal epithelium*. Germ cells which lie in the germinal epithelium or in the mesenchyme of the genital ridge are said to be *regional*, those found elsewhere are *extraregional*. There are three theories as to the origin of the germ cells of vertebrates: (1) That they are developed by the metamorphosis of cells in or derived from the germinal epithelium; (2) that they are entirely of extraregional origin, and reach the gonads by migration; and (3) that they have a double origin—the primary germ cells are extraregional in origin and migrate to the gonads, later secondary germ cells are added by metamorphosis of cells of the germinal epithelium.

The first theory is the oldest and was taught by Waldeyer (1870), Balfour, von Winiwarter (1900), and others, and still has its adherents. Van Wijhe (1889), while studying the development of the ex-

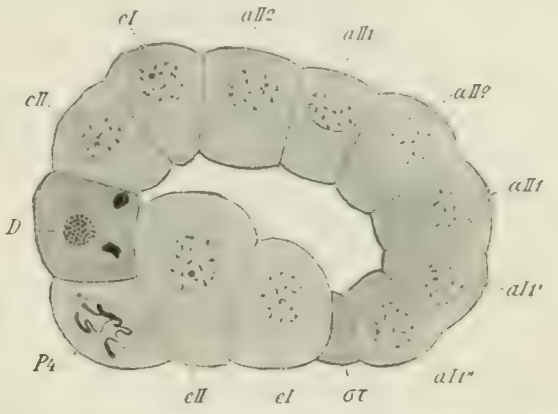

Fig. 2771.—*Ascaris megalocephala*. Optical Longitudinal Section of a Blastula. P_4, Fourth cell of germ track. (After Boveri.)

cretory system, traced the origin of the gonads to a special region of the mesoderm which he called the *gonotome*. Eigenmann (1891) was the first to trace the history of germ cells of a vertebrate to a period prior to the formation of germinal epithelium. In embryos of a viviparous teleost he found germ cells distinguishable from surrounding cells at about the time of the closure of the blastopore.

Three years later Minot (1894) criticized the idea of the gonotome and recorded the presence of germ cells in the mesentery of a young embryo of Acanthias. Wheeler (1899) in young embryos of the

Fig. 2772.—Similar Section of Embryo in the Gastrula Stage. P_5, Fifth cell of germ track, or archigonocyte, dividing to form the first two gonocytes, *UGI* and *UGII*, Fig. 2773. The cell to the left of *dII* is a somatic cell in the same stage of division. (After Boveri.)

amprey found the first recognizable germ cells in the endoderm. Later they become enclosed in an indifferent mass of mesodermal cells, from which they finally migrate to the mid-line above the gut. Rabl (1896) had called attention to the presence of "primitive ova" outside of the genital region in elasmobranch embryos, but Woods (1902) was the first to make a thorough study to test the epithelial origin of the germ cells. In his studies upon the embryos of the common marine dogfish,

Acanthias vulgaris, he has been able to trace the history of the germ cells back to a mass of seemingly indifferent cells forming the rim of the blastoderm (see article *Area Embryonalis*). At first these cells are all alike, but in an embryo of 2.75 mm. length they have become differentiated into somatic cells and so-called primitive ova, that is, primitive germ cells which may become finally either ova or spermatozoa (Fig. 2774). The germ cells retain their primitive embryonic character, while the somatic cells begin to change into forms characteristic of epithelium, mesenchyma, and the like. At a little later stage when the embryo is beginning to fold off from the blastoderm, the germ cells are found in a compact mass in the mesoderm near where it joins the endoderm (*Ur*, Figs. 2775 and 2776).

FIG. 2773.—Longitudinal and Transverse Sections of an Older Embryo. *UGI*, *UGII*, Primordial germ cells beginning to retreat into the interior of the body. (After Boveri.)

From this point the germ cells begin to migrate, apparently by their own ameboid movements, toward the region of the future genital ridge. When the embryo is between 6 and 8 mm. long the unsegmented mesoderm divides into two sheets with the body cavity between. After this the germ cells are practically all found in the inner, or splanchnic sheet, which forms the mesodermal portion of the wall of the gut and the mesentery. In an embryo of 15 mm. (Fig. 2777) germ cells are still to be found in the splanchnic peritoneum, but by the time the embryo has reached a length of 19 mm. these cells have very nearly all congregated in the genital region.

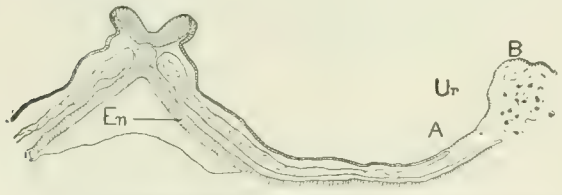

FIG. 2774. Cross Section of an Embryo Dogfish 2.75 mm long. *A–B*, Blastodermic rim containing all the germ cells; *En* endoderm. × 38. (After Woods.)

A similar origin of the germ cells has been found by B. M. Allen (1906) to occur in the turtle and (1911) in two species of ganoid fishes. That is, the germ cells first appear in the endoderm at some distance from the axis of the embryo and migrate through either the mesoderm or the endoderm and the mesentery to the genital region. In the frog Allen (1907) finds that germ cells first appear in the endoderm as a dorsal ridge lying immediately beneath the aorta (Fig. 2778). When the mesentery is formed these cells are pinched off into it, and then pass to the roots of the mesentery and the gonads. This is fully confirmed by Kuschakewitsch and by Miss King.

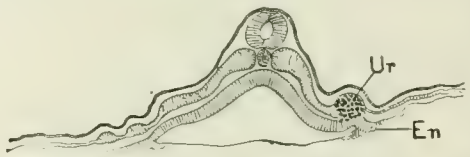

FIG. 2775.—Cross-section of an Embryo Dogfish, 3.5 mm. long. *En*, Endoderm; *Ur*, germ cells. × 38. (After Woods.)

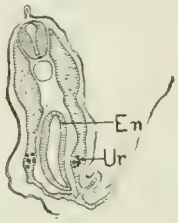

FIG. 2776.—Cross-section of an Embryo Dogfish, 5 mm. long. *En*, Endoderm; *Ur*, germ cells. × 38. (After Woods.)

Felix and Bühler (1906) summarize the results by saying that in holoblastic animals the primary germ cells arise in the region of the gut, in meroblastic animals outside the embryo in the floor of the segmentation cavity, and in the germ wall. This apparently does not hold, however, for the tailed amphibia and perhaps not for the teleosts. There is good evidence (Allen, 1911; Schapitz, 1912) that in normal species of tailed amphibians the germ cells arise in the inner edge of the lateral plate mesoderm, along a line parallel to the Wolffian duct (Fig. 2779).

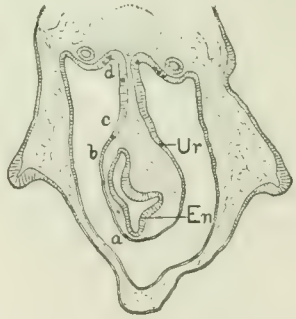

FIG. 2777.—Section of the Ventral Portion of an Embryo Dogfish, 15 mm. long. *En*, Endoderm; *Ur*, germ cells. × 38. (After Woods.)

In most of the species mentioned so far the place of origin of the germ cells has been found in the posterior part of the embryo or area embryonalis. In the chick, on the other hand, Swift (1914) finds the germ cells appearing in the endoderm of the germ

wall at the edge of the area pellucida in front of the embryo (Fig. 2780). When the mesoderm grows into this region the germ cells enter it and penetrate into the blood-vessels. They are carried in the blood stream to all parts of the body, where they can be recognized by their size and especially by the characteristics of the attraction sphere, which appears as a

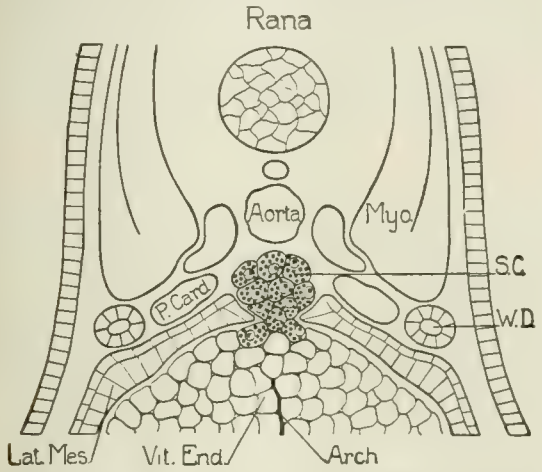

Fig. 2778.—Diagram to Show the Path of Migration of the Germ-cells in the Frog. *Arch*, archenteron; *Lat. mes*, lateral plate of mesoderm; *Myo*, myotome; *P. Card.*, posterior cardinal vein; *S.C.*, germ-cells; *Vit. End.*, vitelline endoderm; *W.D.*, Wolffian duct. (After Allen.)

condensed or flattened sphere of cytoplasm resting usually on the nuclear membrane (Fig. 2781). When the embryo has developed 20 to 25 pairs of somites the germ cells collect in the vessels of the splanchnic mesoderm and leave the vessels. Thence they pass through the splanchnic mesoderm to the radix mesenterii and cœlomic epithelium on both sides, where they remain until the development of the gonad begins.

Fig. 2779.—Section Through Genital Region of an Amblystoma Embryo. *Ekt*, ectoderm; *Ent.*, endoderm; *Myot*, myotome; *Stpl*, lateral plate of mesoderm; *UGff*, germ-cells; *W.G.*, wolffian duct. (After Schapitz.)

Rubaschkin (1910 and 1912) finds in mammals (guinea pig embryos) a means of recognizing the germ cells by the form of their chondrosomes, or mitochondria, small bodies that stain like chromatin, but are found in the cytoplasm. In the germ cells and blastomeres they are rounded granules. In differentiated somatic cells they are drawn out into threads or chains. During the segmentation stages the blastomeres have chondrosomes that are all alike. With the progress of differentiation the number of cells with rounded chondrosomes decreases, until in the stage when the mesodermal somites are appearing,

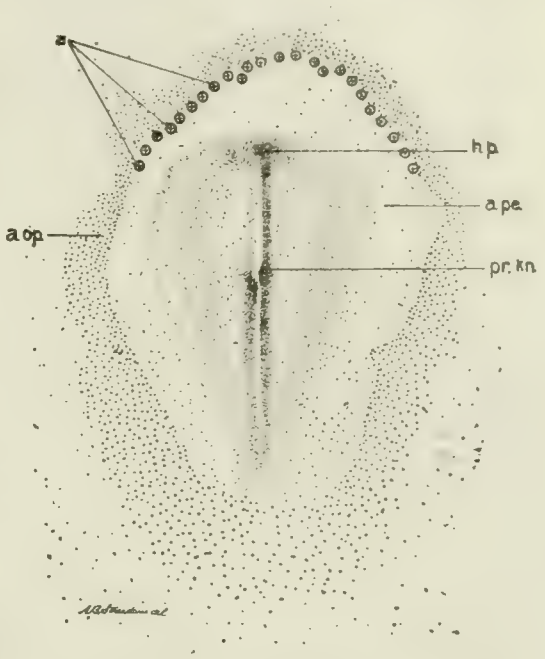

Fig. 2780.—Chick Embryo. *a*, Region where primordial germ cells arise; *a.op.*, area opaca; *a.pi.*, area pellucida; *h.p.*, head process; *pr. kn*, primitive knob. (After Swift.)

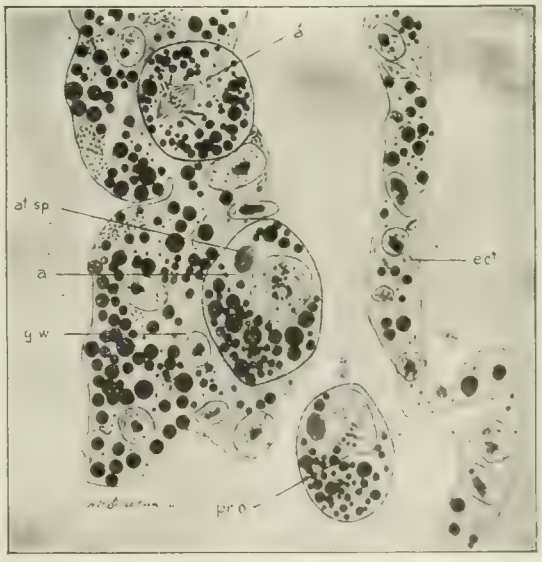

Fig. 2781.—Part of Section of Chick Embryo in Stage of Fig 2780. *a,a'*, Cells of germ-wall that resemble primordial germ-cells; *at.sp.*, attraction sphere; *ect*, ectoderm; *g.w.*, germ-wall; *pr. o.*, primordial germ-cell. (After Swift.)

these cells are restricted to one place, namely at the posterior end of the embryo under the end of the primitive streak. These undifferentiated cells are the germ cells. They remain for a time in the endoderm, then wander into the mesentery and finally reach the

germinal epithelium. After several cell divisions they become oögonia or spermatogonia. Rubaschkin denies that there are any secondary germ cells formed from cœlomic epithelium, which produces follicle cells or other supporting structures only.

Third Period.—The beginning of the third period coincides with the differentiation of the genital ridge into ovary or testis, and in this period the history of the germ cells begins to diverge in the two sexes. In the female the last generation of the gonocytes may produce two kinds of cells. Some produce follicle cells or other cells serving to nourish the eggs, while others give rise to the first generation of *oögonia*, or primordial eggs. The oögonia continue to multiply for an undetermined number of generations. Finally this period of multiplication is followed by a period of growth during which division ceases. The oögonia have now become *primary* oöcytes (see Fig. 2782).

The period of growth is followed by the period of maturation during which two cell divisions occur, usually in rapid succession. The primary oöcyte, having attained its full size, divides very unequally to form the *secondary* oöcyte and the first polar body. Then the oöcyte divides again unequally, forming the second polar body and the ripe ovum, or *ovium* (Greek ᾠόν, egg), as Waldeyer prefers to call it. The first polar body may divide also at the same time, so the maturation divisions result in the formation of four cells—the relatively large ripe egg and three very small polar bodies. The view now universally held, that the polar bodies are abortive eggs, was first stated by Mark in 1881.

These periods in the history of the egg are exactly paralleled in the history of the spermatozoon. In the male the last generation of gonocytes may likewise give

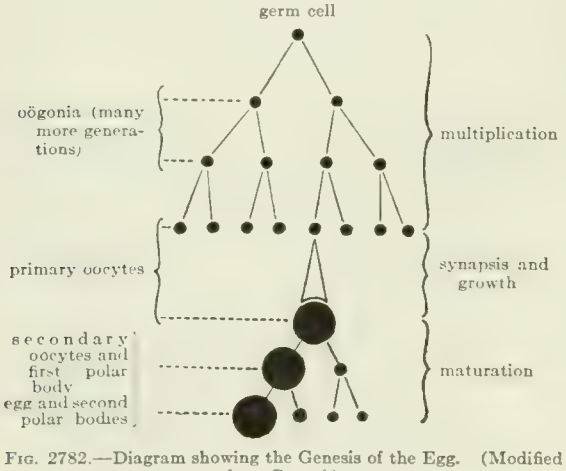

Fig. 2782.—Diagram showing the Genesis of the Egg. (Modified from Boveri.)

rise to nutritive cells and to *spermatogonia*. The latter multiply by division for an indefinite number of generations of cells and the last generation gives rise to primary *spermatocytes*, which then enter upon a period of growth (Fig. 2783). This is followed, as in the egg, by two maturation divisions. In the first the primary spermatocyte separates into two secondary spermatocytes, and by the second division each secondary spermatocyte produces two *spermatids*. Thus the maturation divisions result in the production of four cells, but usually in the male these are all of the same size and all capable of becoming functional.

But in order to become functional the cell must pass through another period, not represented in the history of the egg. This is the period of histogenesis, during which the spermatid undergoes a remarkable metamorphosis by which it becomes transformed into a *spermatozoon* with the characteristics peculiar to its species (see article *Spermatozoa*). With the entrance of the spermatozoon into the egg and the union of the sperm nucleus with the egg nucleus the old cycle ends and a new one begins.

During the periods from the first cleavage of the ovum to the last division of the oögonia or spermatogonia the number of chromosomes present during the prophases of division is always the same in individuals of the same species and is, with rare exceptions, the same as the number found in the somatic cells. But at the beginning of the growth period the nuclei of the

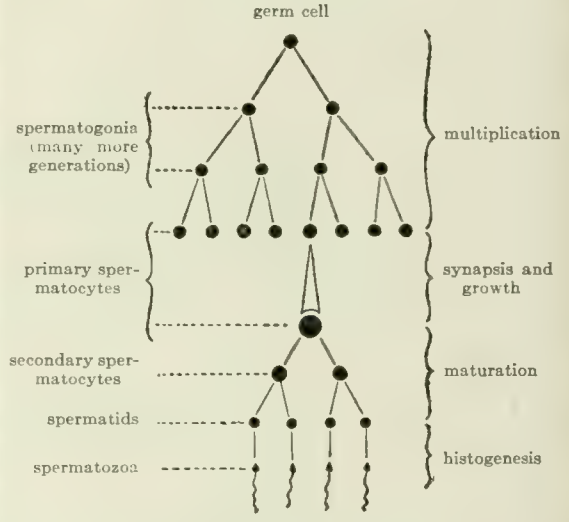

Fig. 2783.—Diagram showing the Genesis of the Spermatozoa. (Modified from Boveri.)

germ cells undergo a remarkable series of transformations, which result in the reduction of the number of chromosomes to one-half the number present in the earlier periods; and the reduced number is found in the oöcytes, spermatocytes, and spermatids, and in the egg and sperm nuclei previous to their union.

Therefore, if a reducing division, as defined by Weismann, really occurs, it is to be sought for in one of the two divisions immediately following the growth period. These are the maturation divisions.

The important events that occur during the third period of the germinal cycle are treated more in detail elsewhere. For an account of the nuclear changes see *Maturation*. The structure and growth of the egg are described in the article *Ovum*, and the histogenesis and structure of the spermatozoa under *Spermatozoa*.

Robert Payne Bigelow.

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Germ Layers.—It has long been known that the bodies of embryos consist of distinct layers, which in many cases are separable from one another, so as to be recognized in gross as discrete membranes. It is now known that all such layers may be reduced to three primitive ones, named the ectoderm, mesoderm, and entoderm (by certain writers, epiblast, mesoblast, and hypoblast). The ectoderm is a layer of epithelium; so also is the entoderm; the mesoderm is more complex. In the lower animals, the mesoderm is less developed than in the higher forms; in the hydroids the body is constituted mainly by the two epithelial layers, the ectoderm covering the outside of the body, and the entoderm lining the digestive cavity; there is very little space between them, the space being occupied by the slightly developed mesoderm. As we ascend the scale the mesoderm increases gradually, constantly acquiring a greater predominance, until in mammals nearly the whole bulk consists of mesoderm. But, in spite of this change, the three layers are preserved throughout, and their essential relations are not altered, so that we are able to assert the unity of organization throughout the whole series of multicellular animals, without which it would be impossible to accept the doctrine of evolution. The demonstration, therefore, of the homologies of the germ layers, is the most important morphological generalization since the establishment of the cell doctrine. As these homologies have already been discussed under *Gastrula*, and also the metamorphoses of the layers under *Fetus*, it only remains for us to review, with precision and brevity, the rôle of the layers in the construction of the human body.

The ectoderm covers the external surface of the body, and persists in adult life as the stratified epithelium (epidermis) of the skin; it forms, of course, all the so-called epidermal structures—hairs, nails, sebaceous and sweat glands, lens, cornea, etc. It also lines part of the buccal cavity; and the buccal portion gives rise to the hypophysis cerebri, to the enamel organs of teeth, and probably to all the salivary glands. It forms a small invagination to meet the rectum, so that it also lines the anus. It gives rise to the entire nervous system by producing the medullary canal, which makes the central nervous system, and from which grow out all the nerves, and probably all the peripheral ganglia, and from which also grows out the evagination which makes the optic nerve, the retina, the choroid, and the epithelial portions of the iris. It forms the epithelium of the olfactory and nasal cavities, and the epithelium of the auditory labyrinth.

The entoderm (also spelled "endoderm") forms the epithelium which lines the digestive tract, including the surface of the tongue; also the epithelium of the trachea and lungs, and of all the glands appended to the respiratory passages and to the digestive tract, including the thyroid, pancreas, and liver. The liver cells, it should be remembered, constitute a true though much modified epithelium. The notochord is developed from the entoderm.

The mesoderm may be conveniently divided into three portions—the mesenchyma, the mesameboids, and the mesothelium (*cf. Cœlom*). 1. The *mesenchyma* produces all the connective tissues of the body, and includes therefore the cutis, the non-epithelial walls of the alimentary tract, etc.; tendons, cartilage, and bone, the marrow of bones, the lymph glands, and spleen; it produces also the blood-vessels and blood, the entire lymphatic system proper, and the heart. Pigment cells, fat cells, and smooth muscles are derived from the mesenchyma also. 2. The *mesameboids* include the leucocytes and wandering cells, and perhaps the embryonic red blood cells, and the marrow cells. 3. The *mesothelium* is the epithelium of the cœlom; it produces the peritoneal and pleural epithelia, the striated muscles (myotomes), except those of the heart, and all the non-mesenchymal tissues of the entire urogenital apparatus, except, of course, the external genitalia. (Spee traces the Wolffian duct to the ectoderm.)

Now, in classifying organs, it is best to rank them as belonging to that layer from which their functionally essential and characteristic part is derived. Thus, although the pancreas, ovary, and spinal cord all contain connective tissue, we do not call them mesodermal, but respectively entodermal, mesothelial, and ectodermal. The gland cells of the pancreas come from the entoderm; the ova and the Graafian follicles come from the mesothelium; the ganglion cells and nerve fibers (axis cylinders) from the ectoderm. Adopting this principle, we may classify the organs of the human body as follows:

Ectodermal.	Mesodermal.	Entodermal
Skin (epidermis).	1. Mesenchyma:	Epithelium (of digestive tract):
Epidermal structures:	Connective tissue:	Thyroid,
Hair,	Cutis, etc.,	Thymus,
Nails,	Tendons,	Parathyroids,
Glands:	Cartilage,	Trachea and lungs,
Sebaceous,	Bone,	Esophagus,
Sudorific,	Marrow.	Stomach,
(Salivary?),	Lymph glands.	Liver.
(Thymus?),	Spleen.	Pancreas,
Corneal epithelium,	Blood-vessels:	Intestine,
Lens of eye.	Blood (in part).	Yolk sac,
Central nervous system:	Lymphatic system,	Cecum,
Nerves,	Fat cells,	Vermix,
Ganglia,	Smooth muscle.	Colon,
Chromaffine cells.	Adrenal cortex.	Rectum,
Eye, optic vesicle:	2. Mesameboids:	Allantois:
Optic nerve,	Leucocytes,	(Bladder).
Retina, etc.	Embryonic red blood cells.	Notochord.
Olfactory organ.	(Marrow cells?).	
Auditory organ,	3. Mesothelium:	
Lining of mouth:	Peritoneum,	
Teeth,	Pleuræ,	
Hypophysis	Urogenitals:	
Anus.	Wolffian body,	
Chorion:	Kidney,	
Placenta.	Testis,	
Amnion:	Ovary,	
(Wolffian duct?).	Oviduct:	
	Uterus,	
	Vagina.	
	Striated muscles.	

The human body may be defined as two tubes of epithelium, one inside the other; the outer tube, epidermal or ectodermal, is very irregular in its form; the inner tube, entodermal, is much smaller in diameter, but much longer than the outer, and has a number of branches (lung, pancreas, etc.), and is placed within the ectodermal tube. Between these two tubes is the very bulky mesoderm, which is divided by large cavities (abdominal and thoracic) into two main layers, one of which is closely associated with the epidermis and forms the body wall, the somatopleure of embryologists; the other joins with the entoderm to complete the walls of the splanchnic viscera, and constitute the splanchnopleure of embryologists. The mesoderm is permeated by two sets of cavities: (1) the heart and

blood-vessels; (2) the lymphatic system. It is also differentiated into numerous tissues, muscle, tendon, bone, etc., and organs, urogenital system. The nervous system, although developed from the ectoderm, is found separated from its site of origin and completely encased in mesoderm.

As we ascend the animal scale, we discover in all parts an increasing complexity; especially in the nervous system is this marked, but it is even more strikingly shown by the evolution of the mesoderm in relative size and differentiation. This important correspondence between the organization of the mesoderm and the degree of evolution of animals has not, to my knowledge, hitherto attracted express attention.

CHARLES SEDGWICK MINOT.

German Measles.—See *Rötheln.*

Germicides.—See *Disinfectants.*

Gestation.—The term means *carrying,* from the Latin *gestatio,* referring to the time of development of the fetus or embryo when it is carried by its mother within the appropriate organ in the body of the mother. Hence we have the common phrase *period of gestation,* that is the period of time during which the mother carries her unborn offspring. The term is not limited to human beings but is common to all animals in which the offspring is developed within the mother's body. It has numerous synonyms, chief among which are gravidity and pregnancy; the latter is in very common use, perhaps in more popular use than gestation and signifies the period before birth. Either term is therefore sufficiently exact in suggesting the condition which is referred to, and they will be used interchangeably in this article.

GESTATION AS A LEGAL TERM.—The term has a very important meaning in law, for it fixes the period of intrauterine life, within which an individual has legal rights in property, etc. Winckel made a careful study of more than 5000 cases of gestation before giving testimony as to its duration before a German court. He reckoned from the day of the presumably effective coitus to the day of delivery. The duration exceeded 300 days in 70 cases and in 47 it exceeded 302, in one it was 314, and in another it was 318. Winckel's conclusions were in the following words "The average duration of pregnancy is about 280 days, it may vary however from 240 to 320 and perhaps even exceed this latter limit which is by no means as rare as was formerly supposed, for in 6.8 per cent. the duration is over 300 days."

By Scottish law and by the French code the legal limit for gestation is 300 days, by the Prussian law it is 301 days, though in a case in which the period was 310 days the court gave judgment in favor of the legitimacy of the child and against the contention of the father. The English law places no time limit but judges each case in accordance with the testimony of medical experts, and the moral and collateral aspects; which is just and sensible.

In this country the English custom is followed and in two cases which are quoted by Leishman, legitimacy being admitted, the duration of gestation, counting from the last coitus, in one case was 313 days and in the other 317. The legal definition of gestation is therefore more for the purpose of establishing a somewhat arbitrary standard than for determining the question with precision. The exceptions from any rule upon this subject that could be established are so numerous that the rule would become of no value. In general it may be said that gestation occupies nine calender months or ten lunar months, and from 273 to 280 days.

Gestation is initiated by conception. Conception results from sexual intercourse in which an ovum and a spermatozoon come into efficient conjuncture or combination.

The fact that the spermatozoa retain their activity and their motility for a very long period shows the fallacy of dating gestation from the last coitus or even from the last menstruation. Heisler tells us that the spermatozoa may remain active in the male genital tract for several days after the death of the individual, and that in the female genital passage they may retain their activity for several weeks. The spermatozoa of the bat if deposited in the female genital passage in the autumn will retain their power of fecundation until the following spring.

EARLY INCIDENTS OF GESTATION.—It is now believed that the fertilizing contact takes place in the Fallopian tube, and that the ovum during the next three to eight days is propelled through the tube to the cavity of the corpus uteri and there becomes imbedded in the mucous membrane or endometrium.

The spermatozoon having penetrated the ovum, losing its vibratory portion in the operation, that portion which has penetrated becomes the male pronucleus. Both the male and female pronuclei then approach each other and unite in the center of the ovum, thus forming the segmentation or cleavage nucleus. As the ovum containing the nucleus passes through the tube to its *nidus* or bed in the endometrium, repeated segmentation occurs, and it is converted into a more or less globular mass of cells, which is called the mulberry mass or morula. By the time the ovum has reached the uterus the blastodermic vesicle has developed and increases rapidly in size. In its progress the ovum has increased from $\frac{1}{125}$ to $\frac{1}{25}$ inch in diameter.

The blastodermic vesicle has two layers, the ectoderm and the endoderm, in the former of which appear the primitive groove and the primitive streak, the first differentiation of form in the new being. Then comes the formation of the mesoderm and from these three primary layers, ectoderm, mesoderm, and endoderm are developed all the organs and tissues of the body.

The embryo first takes the form of a hollow spheroidal vesicle, and as it develops the membranes which surround it and the appendages by which it is nourished develop coincidentally.

The amnion, which becomes the loose sac in which the fetus is enclosed and contains the amniotic fluid in which it is immersed, begins its growth from the fourth to the fourteenth day after conception. It arises from the cells of the inner layer of the mesoderm which proliferate from the under aspect of the blastodermic vesicle and form folds which grow upward and finally unite on its dorsal aspect. As the embryo develops, the amnion develops also and reaches its maximum of growth at the end of the sixth month, persisting henceforward until the end of gestation.

From the lower aspect of the blastodermic vesicle is also projected the umbilical vesicle, or vitelline sac, or yolk sac, which is at first connected by a narrow pedicle, the vitelline duct, with the developing intestinal tube of the embryo and contains material which supplies it with nutriment. The quantity of such nourishment is small, for the main supply comes first from the mucous membrane of the uterus and, after it has developed, from the placenta. The function of the umbilical vesicle continues only from the end of the second to the end of the sixth week by which time it has shrunk to a narrow stalk which eventually becomes a constituent of the umbilical cord. When the umbilical vessel retrogresses the allantois takes its place as the organ of nutrition and respiration. It becomes the medium by which vascular connection is established between the embryo and the villi of the chorion. It sprouts early in the third week from the posterior extremity of the embryonic intestine

through the umbilical opening and develops rapidly into a vascular pedunculated sac, the walls of which soon coalesce and form a vascular membrane. Within a few days it reaches the chorion and spreads over it as a vascular lining. Its vessels penetrate the villi of the chorion and it soon becomes fused with that structure. Its pedicle containing its vessels is eventually converted into the umbilical cord with its two arteries and one vein, which bring nutritive material and oxygen from the mother to the embryo and carry off its waste material. The chorion begins to form after the folds of amnion have united upon the dorsum of the embryo, the outer layer of cells of the amnion swelling until it comes in contact with the vitelline membrane of the ovum which then disappears having accomplished its function. This swollen outer layer has then become the new chorion or outer covering of the embryo, and we have already seen that it is fused with the allantois.

Over the entire outer surface of the new chorion hollow villosities sprout and branch out and as the allantois fuses with it the vessels of the former penetrate the villosities, converting it into a shaggy, very vascular structure. As the ovum develops the villi disappear from about two-thirds of the chorionic surface. Over the remaining third they become greatly hypertrophied and participate in the formation of the placenta. Soon after conception takes place a change occurs in the uterine mucous membrane, its interglandular connective tissue increasing greatly in density and in vascularity and its ordinary smooth surface giving place to folds and convolutions..

After the ovum has arrived from its journey through the Fallopian tube it falls into the depression between two of these folds and from these enveloping folds the *decidua vera* is developed.

At the area of attachment between the ovum and the decidua the maternal portion of the placenta is developed and this portion of the decidual membrane is known as the serotina.

After the ovum has become embedded, usually upon the upper portion of the posterior wall of the uterus, the swollen endometrium or decidua vera forms folds under and over it which finally unite and form a new sac or covering for it with a space containing mucus between this sac and the endometrium or decidua vera, somewhat similar to the pericardial sac. This reflexion and covering is known as the *decidua reflexa*. By the end of the fifth month of gestation the space between the decidua vera and the decidua reflexa is obliterated. During the sixth month the combined vera and reflexa is blended with the chorion.

For the first third of its existence the fetus or embryo is nourished by means of the provisional structures which have been briefly described; for the remaining two-thirds it is nourished by means of the placenta, a discoidal mass of tissue which is attached upon one of its aspects to the wall of the uterus and is connected from its opposite aspect by the umbilical cord with the growing fetus.

The placenta results from the union of the villous structure of the chorion, the *chorion frondosum*, with the *decidua serotina* which, as already stated, is that portion of the uterine decidual membrane which is in immediate contact with the embedded ovum. The villi from the chorion push their way into the soft tissue of the uterine *serotina* and absorb from its dilated capillaries or capillary spaces the nutrient blood from the mother. The absorbing vessels are those which were derived from the allantois, and as gestation progresses the placenta gradually assumes its discoidal shape. The course of the blood current from placenta to fetus is by way of the two arteries of the umbilical cord which bear the blood laden with carbonic acid from the fetus, while the umbilical vein carries it back to the fetus charged with oxygen from the maternal arteries.

The placenta thus becomes not only the organ by which nutrition is carried to the fetus for the development of its structure and the evolution of heat, but the organ of respiration and oxygenation as well, and no living being can exist without oxygen.

The umbilical cord thus forms the medium of attachment between fetus and placenta and, as we have seen, the medium by which nutriment and oxygen are conveyed to the fetus, and waste material borne away from it. It was also mentioned that it was a development from the allantois. The two allantoic veins are eventually fused into one, the two arteries persist. These vessels with the vestigial remains of the pedicles of the allantois and umbilical vesicle are held together by the soft embryonic connective tissue known as the *jelly of Wharton*. The sheath which encloses these various structures is derived from the amnion. The variations in the length of the cord are very great; according to Lusk they are between three and seventy-five inches. Why there should be such variations it is difficult to say.

Within the amniotic sac which encloses the fetus is the amniotic fluid which in the early months of pregnancy is derived from the fetal tissues and from the amniotic vessels which are in relation with the placenta. It is thought that in the latter part of pregnancy it is also composed in part of the urine which is voided by the fetus since it contains albumin, urea, and the saline substances which are found both in serum and in urine. In quantity it varies from one to two pints at the time of delivery. The foregoing, together with the structures and vital forces of the mother, constitute the means or machinery by which gestation is accomplished.

Development of the Fetus.—The changes which take place in the fetus as development progresses must be considered with great brevity owing to want of space.

These divide the period of development into three stages, the first being that of the ovum, or the blastodermic stage, and including the first and second weeks of existence; the second the stage of the embryo, including the second to the fifth week; and the third the fetal stage from the fifth week to the end of gestation.

At the end of the second week of existence the embryonic spot and the dorsal plates are apparent. At the end of the third week the cephalic extremity of the embryo has enlarged, the back is curved, the rudiments of the organs of sight, smell and hearing, and the visceral arches have appeared. At the end of the fourth week the extremities are indicated by minute buds, and the intestine with its two extremities has started. The embryo is then one-third of an inch long.

At the end of the second month the embryo is two-thirds of an inch long. The divisions of the extremities are noticeable, and the lower jaw and clavicle have begun to ossify.

At the end of the third month its length is three and a half inches and its weight one ounce. The neck is formed and the ribs separate the thorax from the abdomen; the lips are formed and the palate separates the nose from the mouth. Most of the bones have begun to ossify, the nails are apparent, also the scrotum, labia majora, penis and clitoris. At the end of the fourth month the length is six inches, the weight two to four ounces, the skull is partly ossified, and the mouth, eyes, ears and nose normal in shape. The sex is distinguishable, the skin is firm, hair is apparent, and there may be fetal motion. At the end of the fifth month the length is seven to ten inches and the weight ten ounces. The head is still large, the face wrinkled, there is hair over the entire surface of the body, and motion can be felt by the mother. At the end of the sixth month the length is eleven to thirteen inches and the weight twenty-three ounces. The eyelids are separate and if such a fetus were

born it might live a few hours. At the end of the seventh month the length is fifteen inches and the weight thirty-nine ounces.

Infants who are born at this age may cry feebly at birth but usually die in a few hours or days.

At the end of the eighth month the length is seventeen inches and the weight fifty-two ounces. The hair on the head is thicker, the nails harder and the navel is nearly in the center of the body. In male children the testicle may be felt in the scrotum. Such children are frequently sufficiently developed to maintain life.

At the end of the ninth month the length is seventeen and a half inches and the weight sixty-four ounces. The body is often well filled out and the skin no longer wrinkled. With care such children are often saved. At the middle of the tenth (lunar) month the length is eighteen inches and the weight seventy-seven ounces.

When born at term the length is twenty to twenty-one inches and the weight, in American babies, from seven to seven and a half pounds, boys being usually somewhat heavier than girls.

If a child is healthy it begins to cry almost as soon as it begins to breathe and moves its limbs vigorously. Within the first few hours after birth there is usually an evacuation of the bladder and intestine, the contents of the latter being known as meconium and consisting of mucus, bile, and cellular material.

Varieties of Gestation.—Gestation may be normal, unusual, or abnormal.

Normal gestation means the formation and development within the uterus of a single fetus, the development proceeding along physiological lines for the mother as well as for the child, and concluding with a fully developed child, or mature fruit, and a mother in proper condition to expel it into the world for its subsequent independent existence.

Unusual gestation means the formation and development within the uterus of more than one fetus, the development proceeding also along physiological lines, while the mother may have an experience during their development which deviates from the ordinary physiological course but is not associated with actual disease. This unusual experience in the mother may also apply to gestation with a single fetus. Both mother and offspring reach the end of gestation in a suitable condition for the performance of the act of labor, the sequel by which gestation is succeeded.

Abnormal gestation means the formation and development of one or more fetuses in an abnormal situation, or with defective structure, or in an abnormal manner. With reference to the mother it means the association of disease or injury during that period while either mother or child or both are unprepared for natural labor or its termination.

Normal gestation is fortunately the lot of the vast majority of women. Theoretically, it should be the uniform experience because it is a physiological act and is an essential part in the programme of nature for the preservation of species. Nature's work, however, is often faulty, however perfect the plan may be, and this fact added to the ignorance, and wilfulness and error of mortals has resulted in the conditions of structure and function of which abnormal gestation has been the inevitable product.

Multiple Fetation.—There can be little doubt that the fertilization of a single ovum and the development of a single fetus at a gestation is the rule of nature for human beings. If this were not so, twin fetation would occur oftener than once in 70 or 80 gestations, triple fetation oftener than once in 3500 to 7000, quadruplets and quintuplets oftener than with their present most extreme infrequency.

Another important fact is that twins are seldom the product of a first gestation, indeed they most frequently occur after the climax of fecundity has been reached. It is also noteworthy that when idiots and imbeciles are susceptible of impregnation they not infrequently bear twins.

Twins may be developed within a single ovum or in two separate ova, the latter being by far the more usual. The two ova may come from a single ovary or from two ovaries, the *corpora lutea* of pregnancy furnishing evidence of this fact. In one of the writer's cases, twins developed in a bifid uterus (I am unable to say whether in one or both cornua) within a short period after one ovary had been removed in connection with an operation for ruptured ectopic gestation.

The unusual nature of twin fetation is also seen in the facts that one or both of them may be deformed or defective, that they may be inseparably joined together, that not unusually they are physically weaker than and inferior to other children, etc.

That impregnation with twins conceived at considerable intervals from each other, the so-called superfetation, is possible is a debatable question, since the fact is pretty conclusively established that when impregnation has once occurred, physiological action is concentrated upon the subject of that impregnation and that alone.

In the reported cases of twins born of a negro mother, one white and one black, there may have been almost simultaneous conception from the white and black sources, or the spermatazoa in the one case may have retained their vitality for days or weeks, or there may have been a bifid uterus; in fact various hypotheses are possible.

Twins may be of the same sex or of opposite sexes, and statistics show that the numbers are about the same for each variety; if they are derived from the same ovum they are always of the same sex.

If twins develop from separate ova each will have its own enveloping membrane, but if the ova are imbedded in the decidua near each other the two placentæ may be united at the border, and the ova may be so near each other as to be enveloped by a common decidua reflexa. If they are developed within the same ovum, the placenta, chorion, and reflexa will be common to both, and there may be two amniotic cavities, or the wall between them may have been absorbed when there will be, of course, but one cavity.

Abnormal Fetation.—One of the most frequent forms of abnormal gestation is abnormal fetation. Under this category are to be included the various examples of twin fetation in which one fetus develops at the expense of the other, as in cases in which the circulation preponderates in one placenta, or in one portion of a double placenta, the badly nourished fetus becoming a monster or degenerating to a mole. It also includes the monstrosities of different types and forms and the large class of ectopic gestation. These abnormalities will be described in detail in other articles.

Changes in the Maternal Tissues and Organs During Gestation.—With the occurrence of impregnation, structural changes at once begin in a woman's generative organs, and as gestation progresses other portions of the body undergo changes also. Menstruation ceases when impregnation begins and is usually in abeyance until the end of lactation.

Uterus.—We have already noted the changes which gestation causes in the mucous membrane of the body of the uterus, and the formation of the three decidual membranes therefrom. The mucous membrane of the cervix of the uterus becomes thick and swollen, and a plug of mucus gradually accumulates in its canal which occludes it and forms a kind of protecting barrier to the growing fetus within the uterine body. The gross appearance is very materially changed. Before impregnation, it is a pear-shaped nearly solid structure weighing one or two ounces, while at the end of gestation it is an ovoidal body weighing two pounds or more. While its outer surface in the first case

measures sixteen square inches, in the second it measures 339. The capacity of its cavity is 519 times greater when gestation is ended than before it began.

The individual muscle fibers of the uterus increase ten fold in length and five fold in width, but their arrangement remains unchanged. Some writers state that new muscle fibers are developed in the early months of gestation, but this is doubted by others.

The blood-vessels, nerves, lymphatics, and connective tissue all undergo great hypertrophy, but the change in the blood-vessels and especially in the veins is particularly marked.

The peritoneum is thickened during gestation, and at its termination lies more or less loosely over the organ which it envelops.

The enlargement of the cervix during gestation is inconsiderable. Its tissues are more or less hyperemic and infiltrated, however, and this results in a physiological softening which often becomes a valuable sign in determining the diagnosis of gestation.

Adnexa.—The ovaries, Fallopian tubes, and broad ligaments all share in the hyperemia and hypertrophic condition of the uterus. The broad ligaments unfold and expand as the uterus enlarges, their blood-vessels, especially the veins, increasing greatly in size and capacity. The round ligaments become greatly thickened, the tubes become lengthened and swollen, and the decidual cells which are found in the mucous membrane explain, at least partially, the possibility of the implantation and development of an ovum in this most undesirable situation.

The ovaries are also somewhat enlarged and hyperemic and may contain cells resembling decidual cells in their stroma. One or both of them will also contain the *corpus luteum* of pregnancy. As the uterus enlarges, the tubes, ovaries, and round ligaments, instead of being located at right angles to the uterus, gradually approach the vertical position until at length they become practically parallel with that organ.

Vagina.—The mucous membrane of the vagina is softened as gestation advances and its glands secrete

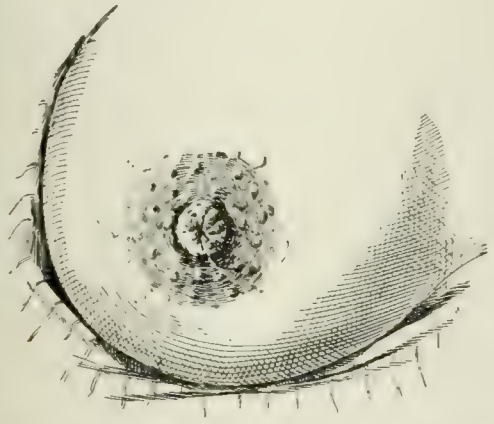

Fig. 2784.—Primary Areola. (Warren's Principles of Obstetrics.)

an abundance of mucus. Its hyperemia becomes more and more marked from month to month until its color becomes purple violet, or almost black. The softness and deep color of the mucous membrane form important data in arriving at a diagnosis. The nerves and muscular fibers also participate in the hypertrophic process, the importance of the latter for the strain and stretch of parturition showing adaptability and design.

Vulva.—The vulva is swollen, its mucous membrane soft, and its vessels enlarged. Its plexus of veins is sometimes enlarged to the bursting point, and the resulting hemorrhage may constitute a very unpleasant complication of labor.

Breasts.—Changes in the mammary glands and their overlying tissues are important and essential for they are the reservoirs for the natural and proper food of an infant after it has been transferred from the interior of the mother's body to the external world. During gestation the connective tissue of the glands swells, glandular acini develop along the course of the lactiferous ducts, and fat is deposited between the lobes.

Fig. 2785.—Secondary Areola. (Warren's Principles of Obstetrics.)

During the fourth and fifth months decided enlargement of the breasts becomes noticeable, the veins around the areola become quite prominent, the lymphatics and nerves are hypertrophied and the nipple becomes elongated and sensitive.

The areola is soft aud raised above the surrounding skin, its follicles stand out prominently and exude moisture, and it becomes darkened from the deposit of pigment. A secondary areola composed of round non-pigmented spots is often formed around the first one in the latter part of gestation, and a milky fluid can be expressed in many cases from the nipple.

Pelvic Joints.—These become softened and there may be separation between their elements. If it were not for this fact natural labor would sometimes be impossible. By means of the Walcher position, which simply means extreme extension of the lower extremities, the pelvic joints may be so relaxed that the capacity of the pelvic cavity will be materially increased and the internal conjugate diameter may be lengthened to the extent of half an inch.

Bladder.—The bladder in the latter months of pregnancy often suffers from pressure and, as it is drawn upward, from tension. This may cause great discomfort and annoyance to the patient from the frequent calls to urinate and from the inability to completely empty it. Cystitis is not an unusual accompaniment of gestation and doubtless has more or less bearing upon the albuminuria of that period.

Stomach and Intestines.—These organs may suffer from pressure particularly in the latter months. In the first three months of gestation the stomach is often the seat of great irritation and rebelliousness, particularly in primiparæ. Constipation is a very common annoyance during the entire gestational period. The appetite which is very capricious during the early months may be greatly improved in the later ones.

Kidneys.—These organs usually suffer little structural change. The albuminuria which is so common in the latter two or three months of gestation is often attributable to the pressure of the enlarged uterus, and eclampsia, that most unwelcome complication, is sometimes similarly explained.

Whether this be true or not, and its truth is denied by competent writers, it is evident enough that the emptying of the uterus will usually relieve these conditions. The excretion of urine during the latter half of gestation is frequently increased as much as fifty per cent.

Ureters.—One or both of these tubes may be displaced or pressed upon during gestation, and cause their dilatation with retention of urine within the kidney. This complication is not of great frequency but its treatment calls for rare judgment when it is present.

Liver.—This organ is sometimes the seat of serious and fatal disease, which seems directly associated with gestation. Recent studies of Stone, Newman and others have thrown great light upon this once very obscure subject. The enlargement of this organ and of the spleen when gestation is associated with malaria and typhoid fever is usually attributable to these diseases and not to gestation.

Heart and Lungs.—These organs may show the result of pressure in the latter part of gestation but the thorax usually accommodates itself to the condition by widening out as the diaphragm is encroached upon. If heart or lung disease is present as a complication of gestation it will frequently prove a very serious matter, either during the progress of gestation or during labor or immediately afterward.

Skin.—Pigmentation of the skin is one of the characteristic accompaniments of gestation. A dark line upon the central portion of the abdomen, often extending from the symphysis pubis to the umbilicus and sometimes to the ensiform cartilage, is especially common. The glands of the skin also manifest increased activity and show increase of secretion. An eruption of acne upon the face is sometimes present and may be exceedingly annoying. Herpes, pityriasis, and fibroma molluscum are occasionally observed. The stretching of the skin of the abdomen during the last three months of gestation causes the appearance of streaks or striæ which may persist indefinitely.

Thyroid Gland.—Enlargement of this gland is of common occurrence during gestation. If an enlargement existed prior to gestation it will persist, but if it is merely an accompaniment of that condition it will subside soon after the gestation has terminated. Like many of the manifestations upon the skin it is an evidence of the metabolic changes which are associated with the present condition.

Bones and Teeth.—The bones are sometimes the seat of osteophytes during gestation and they have frequently been found upon the inner surface of the cranium. Softening of the bones may also occur owing to the abstraction of lime salts, which are transferred to the bones of the growing fetus. The teeth suffer, probably from a similar cause, and it is a common complaint among pregnant women that decay of the teeth begins, or is accentuated, while they are carrying their children. One or more of the teeth may be lost from decay during each gestation.

Nerves.—An unstable condition of the nervous system is not infrequent particularly in young women and during their first gestation.

Hysteria is of very common occurrence and epilepsy may be unusually troublesome at this time. Melancholia and even mania are sometimes observed but not with such frequency as the earlier works on obstetrics intimate. Neuralgia and nervousness, however, are not infrequent and may be very troublesome.

Blood.—The intimate nature of the relationship between the circulation of the mother and that of her growing offspring indicates that changes in the blood are extremely probable. This is especially so in the latter part of gestation when the demands upon the mother for nutrition are very great. If the child is very active and vigorous it is not unusual to observe in the mother, as a consequence, a condition of anemia.

Even under favorable conditions the specific gravity and the alkalinity of the blood are lowered, the red corpuscles show both degenerative and regenerative changes, and the number of white corpuscles is greatly increased. In women with good vital powers the drain may be compensated by increased appetite and the increased intake of blood-renewing food, but women whose vitality is deficient, from any source, frequently show great impairment of strength in consequence of the demands which are made upon the vital fluid.

Weight.—Notwithstanding all the unfavorbale changes which are possible to the pregnant woman, the fact that her condition is purely a physiological one is best shown by the observation that so many women dclare they feel better when in that condition than at any other time, and furthermore because their gain in weight exceeds, often to a considerable extent, the weight of the fetus and the enlarged pelvic organs. Of course this improvement is necessarily dependent upon the fact that the life which is led by the pregnant woman is in conformity with the laws of hygiene and common sense.

Size and Position of the Uterus.—Inasmuch as it is the uterus which undergoes the most decided and significant changes of any organ in the body during gestation it is quite important to give some consideration to its size and position.

Its size in the normal unimpregnated state is quite insignificant, no attention is paid to it at that time, and if it is in a healthy condition no attention is necessary. It is only when it becomes the habitat of a living, growing being that it arouses interest and attention, not only on the part of the woman who is impregnated but on the part of those with whom she may be brought in contact. Attention is rarely called to it during the *first month* of gestation, for it is not until after a woman has missed her usual menstruation that her suspicion is likely to be aroused as to the possible existence of that condition and under ordinary circumstances she would not seek medical advice to determine the question.

In the latter part of the *second month*, roughly speaking, the uterus has become as large as a California orange, of average size, and it is somewhat globular in shape instead of pyriform as in the unimpregnated condition. At the end of the *third month* it is about as large as the head of a new born baby, and its fundus can be felt at the pelvic brim. At the end of the *fourth month* it is as large as the head of a man of ordinary size and can be felt above the symphysis pubis.

At the end of the *fifth month* the fundus is midway between the symphyses and the navel, and from this time onward the shape becomes more and more that of an oval. At the end of the *sixth month* it has reached the level of the navel. At the end of the *seventh month* it rises to two or three fingers breadth above the navel. At the end of the *eighth month* it reaches a point midway between the navel and the epigastrium.

At the end of the *ninth month* it reaches the epigastrium, and between this time and confinement it drops downward and forward, nearly corresponding in position to the level which it had at the end of the eighth month. Inasmuch as the navel is not a fixed point, but was found by Spiegelberg to vary in its distance from the symphysis, in different women, by as great a maximum as six inches that author arranged the following table of distances from the symphysis pubis to the fundus of the uterus for the second half of pregnancy. The measurements were made with a tape over the convex surface of the abdomen and are therefore considerably greater than if measured upon a plane surface.

From the 22nd to the 26th week, 8½ inches.
From the 26th to the 28th week, 10½ inches.
From the 28th to the 30th week, 11 inches.
From the 30th to the 33rd week, 11½ inches.
From the 33rd to the 34th week, 12 inches.
From the 34th to the 36th week, 12½ inches.
From the 36th to the 38th week, 13 inches.
From the 38th to the 40th week, 13½ inches.

These measurements are not invariable, for the size of the uterus depends both upon the size and number of the fetuses which it contains and upon the quantity of amniotic fluid and these are very variable factors. Furthermore some allowance must be made for the size of the woman; a woman who belongs to a family or tribe of which the members are usually very large will have a large abdomen and a large fetus and her measurements will correspond.

The position of the uterus in the successive stages of gestation is well shown in Schultze's diagram. If the uterus were in normal anteflexion at the beginning of gestation it would continue to remain anteflexed or anteverted as it enlarged and ascended out of the pelvic cavity. In the latter months of pregnancy the inclination forward may become less pronounced and the organ will usually be in close proximity with the abdominal wall except when the woman is in the horizontal position when it will recede from it.

In the late months of pregnancy one usually notices that when a woman is standing, she is inclined to throw her shoulders back rather than forward, back of the perpendicular, in order to maintain her equilibrium. The intestines are above and behind the uterus during gestation, occasionally at one or both sides, and rarely in front of it.

It has been said by Pfannkuche that after the uterus becomes an abdominal organ it is twisted somewhat to the right in eighty per cent. of cases and this has been made an argument for opening the uterus somewhat to the right of the median line in performing cesarean section. This may be true, but in the experience of the writer it has not been observed.

If the uterus is retroflexed or retroverted when impregnation takes place it may right itself as gestation progresses. But this fortunate result is quite improbable if it is fixed by adhesions or completely turned into the cavity of the pelvis. In such cases abortion usually takes place unless the situation is opportunely discovered and the uterus released and replaced by one who has suitable skill and discernment for such an operation. Indeed the attempt at replacement may itself be sufficient to bring on uterine contractions and result in the premature termination of the gestation. Since the introduction of the operation for fixation to the abdominal wall of an uterus which has been retroflexed, the so-called ventrofixation, many cases of dystocia have been reported, resulting from the inability of the organ to contract properly on account of the restricting bands which fasten it in front. This would seem to indicate the impropriety of performing such an operation in any case in which it was probable or possible that pregnancy might take place.

The position of the uterus during gestation may also be modified by deformities of the pelvis and vertebral column and these may also be a cause of dystocia from improper contraction of the uterus during labor, or improper direction of the contractile force. This explains the frequent, the almost invariable necessity of interference in cases of badly deformed pelvis, and the futility of depending upon nature to furnish a solution to the situation in the presence of such mechanical disadvantages. Dystocia is also one of the conditions which must be taken into account when one horn of a bifid uterus has been impregnated, or when the position of the uterus is affected by tumors.

Diagnosis of Gestation.—The determination of gestation, particularly in the early months, is very often a matter of difficulty. Even when it is somewhat far advanced, its differentiation from conditions which simulate it is not always easy, and errors in diagnosis have frequently been made by those who were expert and experienced, errors which the laity does not forgive nor condone. In the opinion of the layman it is the business of the physician to know when gestation exists and still more so if he claims, or is supposed to have superior knowledge and experience. The layman makes no allowance for the difficulties and complications which may cloud a situation, and woe to the physician, woe a thousand fold more to the supposed expert obstetrician if he fails to correctly interpret the situation which is put up to him.

Age.—The age of the patient, or the supposed age is a matter of some importance in determining the existence of gestation. Barker, one of the best observers in New York in the last generation, states that he had seen gestation in a child of twelve. The writer has noted it a number of times, as early as the fourteenth year. In India with its child marriages, conception at the tenth year is not uncommon.

In cold climates, among the Norwegians and Siberians and especially among the Esquimaux, conception does not occur before the eighteenth or twentieth year and frequently it occurs without any antecedent menstruation as evidence that puberty has arrived. Barker has seen a first gestation at the fifty-second year followed by a second and a third in the same person at the fifty-third and fifty-fifth years. Legrand du Saulle states that it may occur as late as the seventieth year and the book of Genesis records the case of Sarah in whom it presumably occurred at even a later period (Genesis xviii, 11. "Now Abraham and Sarah were old and well stricken in age; and it ceased to be with Sarah after the manner of women." Genesis xxl., 5. "And Abraham was a hundred years old when his son Isaac was born unto him.").

A diagnosis of gestation is not usually made upon one who has not begun to menstruate, nor upon one who has passed the menopause, but inasmuch as we have seen that gestation is possible before menstruation has appeared and after it has ceased these limits are not absolute in their importance; in general however they are looked upon as the guide posts to the child-bearing period.

Suppression of the Menses.—A woman who has missed a menstrual period, at once suspects impregnation if she has been exposed to that condition. Nothing is more common than for a woman, particularly if she is unmarried, to withhold important data when she visits a physician with a tale that she has gone "three or four days over her courses." On the other hand the suppression of the menses or amenorrhea may be due to disease and not to impregnation, and cruel injustice may be done if a young woman with amenorrhea from such a cause is accused of deceit and prevarication. In young women who are tuberculous or profoundly anemic, from any cause whatsoever, the discontinuance of menstruation is often observed, indeed it indicates nature's endeavor to conserve the vital fluid, every drop of which is needed. Still the rule is that, if the menses fail to appear, conception has occurred or perhaps it is more correct to say that when conception has occurred the menses cease. Not in all cases, however, for there are some women who menstruate or at least have a bloody discharge from the vagina regularly or irregularly during gestation. Indeed it has been said that some women menstruate only when they are undergoing gestation. If such cases are carefully examined there will usually be found some cause for the bloody discharge, other than menstruation. And the menses cease not alone in tuberculosis and anemia but in obesity, especially in unmarried women between the ages of twenty and thirty, with sudden changes of temperature, especially from hot to cold, with an

ocean voyage, with a change of residence from a higher to a lower level and with corresponding increase in the air pressure upon the body, with sudden emotions, such as grief, sorrow, remorse, or fright, and with an early appearance of the menopause which is said to occur among some of the Arabs as early as the twentieth year, and to those women whose reproductive force is exhausted after they have given birth to a single child.

Irritability in the Alimentary Tract.—This is very frequently described as of important diagnostic significance but there are countless cases in which it is altogether absent. It is of very common occurrence with primiparæ, but it by no means follows that a woman will have gastric troubles in her subsequent gestations merely because she had it in her first one. The commonest symptom of all in the group of symptoms referable to the alimentary tract is nausea, with or without vomiting, and inasmuch as a woman is informed of its presence almost as soon as she awakens in the morning it is often known as the "morning sickness." It may excite a woman's attention almost as soon as she has conceived, but it is more probable that it will present itself a few weeks later in which case it seems to be more of a reflex, than of a psychic manifestation. It continues for about three months in most cases and gradually disappears as the uterus ascends out of the pelvis, but it may continue until the end or near the end of gestation. In most of the cases it is limited to nausea, sometimes slight and sometimes almost intolerable, but vomiting may be associated with it and the simplest forms of food or even water may be rejected almost as soon as swallowed.

When ordinary care and judgment are exercised it will usually be brought under control but it may persist and kill the patient or necessitate the emptying of the uterus. If this extreme step becomes necessary one should not wait until the patient is too far exhausted before taking it, and it is always wise to have the confirmatory judgment of a colleague that the operation is essential. With gastric irritability, flatulence, and heartburn, may be associated the formation within the stomach of sour fluids and gases, the latter to be belched up on all occasions and to serve as a frequent cause of annoyance and mortification. Another associated symptom which frequently occurs with young women and especially with primigravidæ is salivation, the saliva often being thick and tenacious, very copious, and difficult of ejection. Women who are pregnant may also have an abnormal appetite, a longing for food and drink which are utterly improper, and a loathing for what they ought to desire; the appetite may even be perverted in a manner which is disgusting.

Quickening.—This is the old English term for the awakened consciousness on the part of the mother that the fetus within her is a living being. It is a sensation of motion within her uterus like the "fluttering of a bird" as it was once expressed to the writer. This sensation comes between the twelfth and the eighteenth weeks of gestation.

It is usual to tell women that they may expect it in the middle of the fifth month, that is when gestation is half over. The motion is first expressed by a gentle tap and as time progresses the taps become frequent and active. Not only are the fetal movements felt by the mother, they can be seen by inspection of the abdominal wall. Women who are not pregnant but who long to be, have often been deceived as to the supposed fetal motions. If they have been anything more than a figment of the imagination they have turned out to be the motion of gas within the intestine. The real fetal movements are the more noticeable upon the abdomen when the quantity of amniotic fluid is small. They may be excited by placing a cold hand upon the abdomen, or by gently tapping one or the other side of the uterus with the fingers. When these movements can be noted with precision they leave no doubt as to the existence of gestation.

The Breasts.—This group of signs is very important in determining a diagnosis of gestation. The breast enlargement is not a new deposit of fat and connective tissue. It is an increase in the lobules of the gland and in the nodules which are connected with them, the enlargement extending from the periphery of the gland to the center. The breast of the pregnant woman also has silver lines due to the tension of the skin, especially in her first pregnancy, like those which are upon the abdomen. The veins form a distinct plexus around the areola, which is not apparent on the healthy breast of an unimpregnated woman. The areola is darker than in the non-pregnant, stands out above the skin, and the follicles of Montgomery are characteristic. The presence of milk or a milky fluid may help in the diagnosis but it is not always present and it may be in the breast of a woman who is not pregnant. The secondary areola may be present after the fifth month but it is not a constant sign and is not essential to the diagnosis.

Abdominal Signs.—For the abdominal examination the patient lies upon a table in the dorsal position with the thighs properly flexed, and the abdomen bared. Inspection reveals abdominal enlargement after the third month, the enlargement being fairly symmetrical and the surface convex. The pigment line in the center of the abdomen should be noted and also the striæ upon either side of it due to the stretching of the skin.

Palpation should next be made with both hands, the hands being sufficiently warm to avoid the productions of contractions from the underlying tissues. The condition of the tissues of the abdominal wall should be noted, greater firmness being usually present in primiparæ than in multiparæ. The outlines of the uterus should be carefully defined, especially at the fundus. Then the contour of the fetus should be determined as carefully as possible, especially with relation to the presenting end, and the vigor of the fetal movements observed. Abdominal ballottement may be practised by sharply pushing the fetus with one hand and receiving the responding impulse at the other side of the uterus with the other hand. This sign is not essential and can be effectively developed only when the uterus contains, relatively to the fetus, an abundance of liquor amnii.

Fetal movements in healthy children are easily excited after the sixth month. Contraction of the uterine muscle may be obtained by stroking the abdomen with the hand over the uterus, up and down and from side to side. These contractions will not result if the underlying body is an uterine or ovarian tumor.

Auscultation forms a very important part of the examination and enables one to detect the rate of the fetal heart action, and the circulation of the uterus, the so-called uterine souffle. The auscultation may be made with the unaided ear or with the phonendoscope.

The writer prefers the former method but it is often desirable to use both. A thin napkin or handkerchief is laid over the abdomen and the ear passes over the surface until the fetal heart sounds at the point of greatest intensity are made out. It is well to have a finger upon the radial pulse of the mother at the same time. The fetal heart beats may be heard at any time after the eighteenth to the twentieth week. They vary from 120 to 160 per minute and are more frequent in females than in males. Their rhythm is exactly like that of the mother's heart but nearly twice as rapid. They are best heard over the dorsum of the fetus and when the dorsum faces the mother's abdomen. They are less audible when the mother's abdomen is very thick, and when the liquor amnii

is abundant. This sign is of the greatest importance and if after repeated careful examinations it cannot be made out the presumption will be that the fetus is dead.

Auscultation will also enable one to determine the position and presentation of the fetus, and to detect a plural gestation.

The uterine souffle or bruit is a blowing sound which is heard along the left side of the uterus and is synchronous with the mother's pulse. It is produced by the motion of the blood in the uterine artery and its branches. It can be detected after the fourth month and persists to the end of gestation. Its value as a sign of gestation is lessened by the fact that it may also be heard when the uterus is enlarged from other causes.

Vaginal and Vagino-abdominal Examination.—A vaginal examination may be made with the forefinger of the left hand or with the forefinger and middle while the patient is standing, or lying on a table upon her back. Two fingers are much better for the examination than one, for the middle finger will penetrate half an inch further into the pelvic than will the index alone. The single finger must usually be preferred when the patient is a primipara and when the external genitals are rigid. While we have frequently made use of the standing position we do not see that it gives any information which may not be obtained from the dorsal position and for routine purposes the latter is to be preferred.

The legs must be widely separated and the thighs flexed, the feet resting upon the base of the table or in stirrups. It is always important that there be no unnecessary exposure of a patient, a sheet of ample dimensions covering all but the external genitals. A woman very quickly forms her estimate of the modesty and consideration of a physician by the way he makes a vaginal examination, and the more skilled he is the more gentle will he be in his manipulation, and the more thoughtful for his patient's feelings. It need hardly be said that the external genitals should be carefully cleansed before the examination with a warm antiseptic solution, and it will also be well for the sake of thoroughness, to give a vaginal douche. If the physician does this himself he will be sure that it will be done properly. He must also prepare his hands and finger-nails with great care and if they are absolutely clean he may use his judgment about putting on rubber gloves. A physician who is as careful as he ought to be will not infect his patient whether he wears gloves or does not wear them. The labia are first separated with the fingers of the two hands, and the mucous membrane and skin of the vulva and vagina are inspected.

If these tissues are darker than normal, gestation is probable, the darker they are the more probable is gestation. If the veins of the vulva and vestibule stand out prominently, still more is it probable that there is gestation. The discoloration begins as early as the second month, the enlarged veins belong to the last four months of gestation.

Introducing the finger or fingers into the vagina if the mucous membrane is soft and moist with secretion the suspicions of pregnancy become more intense. Advancing further, if the cervix is soft and the os pouting or patulous we have additional evidence of the probability of gestation. If the patient is a primipara the os will be very small and the cervix usually conical; if she has already borne children, the cervix will be cylindrical, the lips of the os more or less everted, and there will be more or less mucus in the cervical canal. As the finger passes along it will note anything unusual in the condition of the urethra and whether the rectum is empty or contains fecal matter. It will then pass around the vaginal vault, observing the condition of the bladder, determining whether the uterus is anteflexed or retroflexed and discovering, if possible, a boggy and compressible condition of the lower segment of the body of the uterus. This is Hegar's sign, one of the earliest of those which indicate impregnation and may be developed from the sixth to the eighth week of fetal life. If the two fingers are placed in the anterior vaginal fornix and compress the tissues upward sharply and suddenly, and if the time is between the fifth and sixth month of gestation, the fetal body will be impelled upward in the liquor amnii in which it is immersed and then will sink down again, the fingers recognizing the return tap.

This procedure is known as internal ballottement. It used to be regarded as a very important sign of gestation, but it is not of much use before the fifth month and after the sixth month the quantity of fluid in the uterus relative to the fetus is too small to make it valuable. It is therefore to be regarded only as one of the confirming evidences of impregnation, out of many which have previously become available.

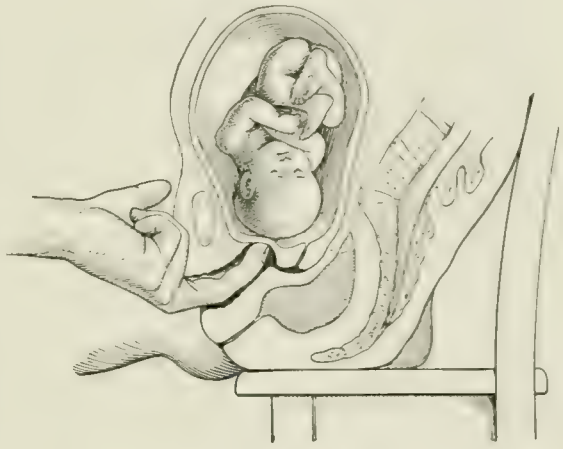

Fig. 2786.—Ballottement.

With the fingers still in the vagina the other hand may be used upon the abdomen to find and outline the body of the organ. This may be done the more accurately by pressing the fundus downward and thus holding the organ between the two hands. This is the vagino-abdominal examination and enables one to determine the size and outline of the uterus, to note the presence of the fetus and of fetal movements, to determine softness, bogginess and resiliency of the uterine tissues when they are present, and is consequently a method of great importance during the first four or five months of gestation.

Examination by the rectum may be used to confirm Hegar's sign and determine with greater accuracy than by the vagina, the condition of the uterine adnexa. It is a rather confusing experience until one is quite familiar with the sensation which it evokes and should not be depended upon for diagnosis by the inexperienced.

Differential Diagnosis.—In order to properly estimate the value of the various signs of gestation which have just been mentioned, account must also be taken of other conditions which may render those signs misleading or unreliable.

The uterus may be somewhat enlarged and simulate that organ in the early weeks of pregnancy, in consequence of chronic metritis or fibroid development; but it is neither so soft nor so resilient as the pregnant uterus.

An anteflexed uterus should not be mistaken for the pregnant organ, for, though it may have the sharp angle between cervix and body of the pregnant organ, it is usually smaller, rather than larger, than the latter, and it is almost invariably harder and more

dense. An ovarian cyst or an enlarged Fallopian tube closely adherent to the uterus and moving with it may suggest gestation, but the other early signs of the latter are usually wanting and menstruation is either unaffected or the volume of the discharge is increased. A retroflexed uterus may suggest gestation and may even be impregnated but the objections are the same as for the other conditions just mentioned.

Suppression of the menses as already stated may be due to causes other than gestation, besides if the uterus is very small that condition may be excluded. A symmetrical fibroid tumor, with milk in the breasts and discoloration of the vaginal mucous membrane, may deceive the very elect, but an examination under anesthesia will usually clear up the diagnosis, besides pregnancy may coexist with it. Gas in the intestines has been mistaken for gestation, especially in women who are very anxious to be pregnant. A good dose of castor oil or a turpentine enema will promptly reveal the cause of the enlargement.

Ascites and obesity if they are the only evidences of gestation will seldom mislead. In ascites if the patient is turned upon her side the fluid will gravitate to that side, and in obesity the mass of fat can usually be gathered up between the hands and demonstrated to be a part of the abdominal wall. Tumors of various kinds which are low in the abdomen have often been mistaken for the pregnant uterus, but the careful isolation of the latter organ and the absence of other important signs of gestation will reveal the error. Still, erroneous diagnoses have often been made by mistaking the pregnant uterus for a tumor and *vice versa*. Repeatedly has an ovarian tumor in an innocent girl been declared the pregnant uterus, and repeatedly has the abdomen, and in some cases even the uterus, been opened only to reveal gestation instead of an ovarian tumor. A pregnant uterus containing a dead fetus may offer great difficulty in diagnosis. The points which have been of assistance to the writer in such cases are the cessation in the enlargement of the organ, the consciousness on the part of the mother of the absence of fetal activity, the want of response on the part of the fetus to stimuli of various kinds, a feeling of coldness or blunted sensation in the uterus and a sensation of bogginess upon palpating the uterus which is totally unlike the feel of the uterus when the fetus is living. Most important of all there is a total absence of fetal heart sounds, which is conclusive of the situation.

The Management of Gestation.—This includes the care which the woman should give to herself as well as the supervision which she should receive from her physician.

Many women go without medical attention or oversight from beginning to end and there is no denying that they often do as well as if they had such attention; doubtless in some cases they do better, for gestation as well as midwifery may be meddlesome and bad.

Assuming, however, that a woman needs advice and attention, she should be in close communication with her physician in order that he may detect any unusual development at the earliest possible moment.

Her diet should be simple, she should be as little burdened with household or society cares as possible, and if nausea and vomiting are troublesome she should take her breakfast, and a very light one at that, in bed preceding it by the slow ingestion of a cup of hot water.

Bathing, including the daily vaginal douche, and a rectal enema when necessary, and rubbing not only result in the removal of the dirt and worn out epithelium from the skin but they favor glandular activity and assist in the processes of elimination. If the skin is rubbed thoroughly at night with fresh cocoanut oil it will add greatly to the patient's comfort and will encourage sleep, of which a pregnant woman like a pregnant animal needs a great deal. The ordinary household duties give plenty of exercise, especially if they call the patient out-of-doors part of the day. If she does not have such duties she should find agreeable but not violent exercise daily. She may walk an hour a day; she may even play golf until the last weeks of gestation. She may not play tennis except in the first two months, and violent exercise like horseback riding or riding in an automobile over rough roads should be interdicted.

Her clothing should be loose enough to permit perfectly free circulation, it should be warm and abundant in winter without exposure of the neck or legs, and thin and light in summer. When the abdomen becomes pendulous it may be supported by a stout flannel binder.

The rooms of the house or apartment must be well-ventilated and she should be encouraged to practise deep breathing at least five or ten minutes night and morning. The breasts must be carefully watched, if they are sore and rigid they should be gently massaged and the nipple should be kept clean, especially during the last two months of gestation, with a daily application of boric acid solution. The nipples if retracted may be drawn out with a breast-pump, but one may easily do harm by too much meddling with these sensitive structures. It is very desirable that the urine should be examined at frequent intervals, as often as once in two weeks during the early months of pregnancy and once a week in the last two months. If symptoms in the patient or the condition of the urine suggests it, examination may be necessary every day.

In a word, the management of gestation should inculcate the greatest simplicity in eating and drinking, and the avoidance of all excesses including sexual intercourse. The latter should be prohibited during the last two months; premature labor being often the result of failure to observe this positive dictum.

The physician should examine his patient as often as her situation demands it and since he is to take the responsibility of seeing her through her labor he must be the judge as to the necessity of examinations. He must not neglect the careful examination of the pelvis and it is always desirable to keep a record of the measurements. This may save a lot of trouble when the time for labor is at hand.

The Pathology of Gestation.—This is easily divided into medical and surgical departments and the knowledge in both of them has greatly widened within the last few years. We shall not attempt to consider the pathology of the fetus nor of its appendages, these like ectopic gestation will be taken up elsewhere. Only the most recent text-books on obstetrics contain comprehensive considerations of this most important aspect of gestation, that is the considerations relating to its pathology.

Medical Pathology.—*Disturbances of the Alimentary Canal.*—There is probably no group of symptoms which affect women who are undergoing gestation, which equals in frequency those which affect the alimentary tract.

Salivation.—The condition may be extreme or only moderate. Lusk states that as much as two or three quarts of saliva per day may be ejected. He advises for its relief small doses of atropine, or of fluid extract of viburnum prunifolium.

Gingivitis or Stomatitis.—One or the other of these is said by some foreign writers to be present in sixty per cent. of the cases of gestation. With the writer they have been of infrequent occurrence. They are thought to be evidences of toxemia. Locally the mouth should be disinfected with a solution of boric acid or of menthol, using it as a mouth wash every hour or two. Bleeding from the gums is a rare manifestation; it may occur together with nosebleed in

women whose blood is deficient in fibrin. Salts of calcium are required in such cases.

Flatulence and Heart-burn.—These are frequently very troublesome indications of indigestion and may continue through the entire period of gestation. The eructations and the fluids which are spat up are usually sour and acrid. Simple treatment consists in taking copious drafts of very hot water with or without the addition of an acceptable aromatic. It makes little difference whether the water is retained or not, if vomited the dose should be repeated. It may be followed by an alkaline draught like the hydrated magnesia, or the aromatic spirits of ammonia suitably diluted.

Nausea and Vomiting.—No symptoms are more common or more troublesome than these. Comparatively few of those who are well-to-do, that is who have the leisure to stop and think of their symptoms, and especially of those who live in cities, escape this annoyance. This comprehensive statement is especially applicable to primigravidæ. The symptoms may end as the uterus rises from the pelvis but in a minority of cases they persist to the end of gestation. A great variety of measures have been recommended, but every physician should have sufficient initiative to treat each of his cases on its merits. Rest in bed is usually most important, though patients have told the writer that in their cases it was exaggerated by rest in bed. Occasional emptying of the stomach with hot water, simply drinking a quart or two or pouring it in with a stomach tube and then siphoning it out has served the writer well. Mustard to the epigastrium is often very efficient and satisfactory. The old-fashioned mixture of bismuth, cerium and bicarbonate of sodium is a good stand-by. Do not give morphia or any form of opium until other things fail, but it will quiet the stomach when nothing else will do it. Champagne, vichy, and carbonic acid water, chloral by rectum, etc. may be tried and they are frequently efficient.

When the vomiting becomes uncontrollable and the question becomes one not of saving the child but of saving the mother, the uterus must be emptied and it should not be done by one who is unfamiliar with the conditions within the pregnant uterus, that is, it is always best to have expert assistance or counsel unless one is entirely familiar with what is required. The operation is not always easy, it is often followed by sepsis, and not infrequently the uterus is perforated with fatal result. It is an operation which is seldom required and should always be done with the approval of a consultant. Rectal alimentation should be tried before emptying the uterus and if this fails the operation must promptly be resorted to. In a minority of cases the vomiting takes the pernicious form almost from the beginning. It is uncontrollable and almost continuous and, of course, rapidly weakens and exhausts the patient.

If its progress could be foreseen, the prompt emptying of the uterus might relieve the symptoms, but it is of little use to perform that operation when the patient is almost moribund. Besides it is not infrequently a symptom of an incurable organic disease of the liver, kidneys, or other organs. In some cases the vomiting ceases spontaneously or perhaps in consequence of judicious treatment, but such cases are rare indeed.

Tympanites.—In connection with the disturbances of the stomach, there is frequently intestinal disorder also, including intestinal indigestion and fermentation with the abundant development of gas. The intestines may be greatly distended and cause great annoyance and pain. If possible those, who are thus affected should remain in bed most of the time, eating only such food as can be readily digested and including dry toast, clam broth, beef extract, kumyss, wine, whey and other simple substances, preferably fluids. While in bed a rectal tube may be worn and if this does not release the gas a hot soap and water enema with the addition of a teaspoonful of turpentine to the pint of water, thoroughly mixed, may be given as occasion requires.

Constipation.—This is one of the most common complaints among pregnant women. It must be successfully combatted at all hazards, but no drastic cathartics and no mercury should be administered. An occasional enema with or without oxgall, fluid extract of cascara, phenophthalein, and above all castor oil may be administered with sufficient regularity to keep the bowels freely open. The intestines and the kidneys are the chief means for the elimination of the wastes of the body. If they are restricted in their action it means more or less septic absorption and toxemia for the mother and perhaps for the child. The most scrupulous regard for these facts will obviate many of the ills from which pregnant women so frequently suffer. Diarrhea is of occasional occurrence during gestation and may be associated with some of its toxic symptoms; it is more frequently due to errors of diet, and should then receive the same treatment as if unassociated with gestation.

Kidney Lesions.—Inasmuch as the kidneys share with the intestine the principal part of the work of eliminating the wastes of the body, their condition during gestation has always received much attention from careful clinicians. A woman may enter the period of gestation with diseased kidneys or kidney disease may develop during gestation. In the former case we have usually the contracted kidney with granular changes in the tissues and granular casts in the urine, in the latter we usually have the acute parenchymatous nephritis with albuminuria, hyalin, and epithelial casts, edema, and the usual symptoms of acute Bright's disease. The chronic form of the disease is of especial malevolence at this time because of its association with eclampsia at the end of gestation or in connection with labor, and this whether or not we accept the theory that it is identical with the convulsions of uremia. All the measures which are useful in treating these diseases in the non-pregnant state must be remembered in those who are pregnant. The presence of bile elements, albumin, sugar, or diminished volume of urea in the urine, calls for redoubled care and caution in the management of the patient and when, as often occurs during the latter weeks of pregnancy, the albumin increases to fifty or sixty per cent. or even more, and the quantity of urine is greatly diminished, such active measures as cupping the kidneys, and the use of suitable diaphoretics must be promptly brought into requisition or, in urgent cases, the bringing on of labor prematurely. In doubtful or serious cases it will be essential to have careful laboratory tests from time to time of the various nitrogen compounds in the urine and thus follow the internal changes which are going on.

Eyes.—Frequently associated with the kidney lesions of gestation are well marked eye symptoms. Albuminuric retinitis is looked for with nephritis and is an important diagnostic symptom. Loss of vision may occur in the latter part of gestation and may be a transient or a permanent condition. It is supposed to be due to an optic neuritis.

Liver Disorders.—Jaundice and pigmentation of the skin have long been recognized as evidence that the liver had much to do with the pathology of pregnancy. The jaundice in the new-born while distinct from the jaundice in the mother during gestation, is at least an evidence of the involvement of the fetal liver also during that period. The subject has recently been studied by many investigators both in this country and in Europe. Stone in 1903 advanced the theory of the hepatic origin of the toxemic condition in gestation, functional disturbances in the liver setting up changes in the liver cells which result in the formation of intermediary products of metabolism, the latter acting as poisons to the blood. He finds the proof, perhaps

provisional, of his theory in the predominance of hepatic lesions in fatal cases, in urinary changes and in the clinical relationship between acute yellow atrophy and allied hepatic diseases, and pregnancy. He admits, however, that this theory furnishes no evidence of the primary nature or of the source of the poison.

Skin Phenomena.—In addition to jaundice during gestation many other pathological phenomena upon the skin are noticeable during gestation. Pruritus with or without an erythema may occur on any portion of the surface. It is especially troublesome upon the external genitals and around the anus and is most annoying at night and in cold weather. Applications of a thick mixture of glycerin and tannin may be carefully rubbed upon the itching surface and also a solution of nitrate of silver of moderate strength. The writer has found the former of these very efficient. Besides pruritus gestation may be complicated with eczema, urticaria, pemphigus, herpes, impetigo and probably with other dermatoses.

If the diet is correct and the emunctories of the body in active condition there is little probability of the occurrence of such complications.

Pain.—Pain in the form of headache, neuralgia, tooth-ache, etc., is a frequent accompaniment of gestation and may be more than incidental. To what extent these conditions are reflex it is not always easy to say. The hypersensitive condition of the nervous system during gestation doubtless leads to their outbreak upon very slight provocation or irritation. The teeth must be kept as free from caries as possible, antiseptic mouth washes being constantly used. The loss of lime salts from the bones and the teeth to the growing fetus must be made up, if possible, by the ingestion of assimilable preparations of lime. For pain in the head and face the faradic current will often be found efficient, also the application of heat. External remedies, if possible, are preferable to internal. The unstable equilibrium of the entire nervous system of many women while they are pregnant leads to a great variety of nervous phenomena which may be considered on the border line between the physiological and the pathological. To this category belong the hysterias, the abnormal sensations of touch, taste, and smell, insomnia and aberrations of mind and will. They are more apt to occur in women of an emotional or excitable temperament than in others. They do not often result in insanity, and if they do the prognosis is usually good, and with the ending of the puerperium they have in most cases disappeared. Medication is seldom required for these conditions, but if it should seem desirable a simple sedative like asafetida, valerian, or scutellaria may be given.

Blood.—The condition of the blood during gestation is not altogether the same as at other times, there is a loss of red corpuscles and albumin, there is an increase in water so that it is often spoken of as a condition of hyperemia. This accounts for many of the unusual phenomena of gestation, for the loss of appetite and memory, for indigestion, and the various evidences of nerve instability, for weakened heart action and the venous stasis with its accompanying effusion of serum into the tissues, otherwise known as edema or dropsy. Instead of hyperemia the condition may be one of marked anemia, and will call not only for a very carefully selected and nutritious diet but for the use of a reliable preparation of hemoglobin. If the condition becomes one of pernicious anemia the prognosis will usually be bad in spite of all that medicine or food can do.

In most of the abnormalities which have been alluded to in the foregoing paragraphs it is now considered by many writers that a condition of toxemia is present which makes the determination of prognosis in any given case somewhat uncertain. It would seem to the writer that the subject has been rendered rather more confusing and complicated than is warranted for a condition which is physiological in the vast majority of cases. The test of any treatment is the result of treatment which is recommended by it, and no very startling results have as yet been reported. So far as academic discussion is concerned it is, of course, interesting and informing.

Incidental Diseases.—Pregnant women are usually more sensitive to disease especially to the infectious diseases than are others. The importance of such complications is accentuated from the fact that the fetus may also be implicated and perhaps lose its life. This is particularly apt to be the case with variola, rubeola, and scarlatina, and these diseases in the past have also frequently resulted fatally or at any rate in abortion for the mother. Typhoid and malarial fevers not infrequently complicate gestation and endanger the lives of both mother and child.

Pneumonia and pleurisy also occur and run a course which is not essentially different from their usual course. In all these diseases, however, the danger of abortion or miscarriage is ever present and is not of infrequent occurrence. Syphilis in the pregnant woman is a large subject and can be referred to only with great brevity at this time. A syphilitic woman may conceive and pass the disease to her offspring. A woman may contract syphilis during pregnancy and the fetus will not receive the syphilitic influence from its father, but from the fresh and virulent characteristics of the disease in its mother.

The use of neo-salvarsan or hectine with mercury offers a promising field for the treatment of both mother and fetus.

Surgical Pathology.—*Varicose Veins.*—This condition may develop during gestation and especially if there has been a previous tendency to enlargement. The veins of the legs are often thus enlarged and may result in phlebitis especially during the puerperium. The veins of the vulva are often enormously enlarged and become a source of great anxiety during labor. The enlargement results from pressure and venous stasis as the uterus increases in size in the last months of gestation. The veins of the breast always become enlarged and prominent but seldom give rise to trouble. Operations upon these veins are seldom to be thought of, they should rather be treated by rest in bed, elevation, and suitable pressure from a bandage moistened with a soothing and astringent lotion.

Hemorrhoids.—These are also frequently very troublesome during gestation and may become very large and painful or they may burst and result in copious hemorrhage. They must be carefully dressed and all precautions taken to avoid sepsis. When they are troublesome in the early months of gestation before the uterus has ascended out of the pelvis, they should be operated upon in the simplest manner possible for they will surely give great trouble in the late months and during labor if this precaution is neglected.

Abdominal Tumors.—Gestation is frequently complicated by both uterine and ovarian tumors, and they may grow very rapidly during that condition. Whether they should be removed or not during gestation is a most trying question to decide. If they interfere with the growth of the fetus, they must be removed or they will cause abortion, and if their removal is attempted, abortion will frequently result. It is astonishing how much insult the pregnant uterus will sometimes tolerate, for interstitial fibroids involving a considerable portion of the uterine structure have been removed in numerous cases, the gestation remaining undisturbed.

Submucous fibroids which obstruct the uterine and vaginal passages must be removed to facilitate labor, and should be removed as early as possible in gestation. They may sometimes be pushed out of the way of the fetus during labor, but such a chance should not be taken if it can be avoided.

Uterine Displacements.—These may occur in almost any form as an incident of gestation. Anteflexion is the normal inclination of the uterus, if it becomes extreme when the organ is very heavy the latter should be supported by an external bandage. The recti muscles may separate during gestation or there may have been a previous ventral hernia and the anteflexed uterus may slip through the opening. An operation may be done for the relief of the hernia and in favorable cases should be done to facilitate labor, but the risk of inducing miscarriage thereby must not be forgotten.

Retroflexions of the uterus must be corrected and should be corrected early in gestaton. If the retroflexed uterus is adherent an abortion is likely to occur, or should the gestation proceed to term the labor will be a difficult one because of misapplied mechanical force. The same is true if the uterus is adherent after an operation for ventrofixation to the abdominal wall, and the unfavorable experience in numerous reported cases shows the importance of liberating the uterus before labor takes place. Lateroflexion of the pregnant uterus is seldom sufficiently acute to cause trouble; in the writer's personal experience it has never occurred. If it becomes troublesome it should be relieved by means of a properly adjusted bandage. Should gestation occur in a prolapsed uterus the prolapse will become intensified as gestation progresses, for such a situation occurs almost invariably in cases in which the vaginal walls are greatly relaxed. Spontaneous abortion will occur in some cases, in others the labor may take place rapidly and possibly with resulting inversion of the vagina or the uterus or both. During gestation the uterus should be replaced and supported as well as possible but it is doubtful whether an operation during that period would be permanently successful or even efficient as an aid to labor. If the uterus is still within the vagina when labor takes place the labor will usually be a difficult one and the pressure upon the relaxed vaginal tissues may lead to sloughing or to other serious injury.

Surgical Conditions in General.—These must be treated on well-recognized surgical principles. The recent results of aseptic operations during gestation have been good, but if they can readily be deferred until the puerperium has terminated it will usually be to the advantage of both mother and child.

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Gestation, Ectopic.—By this term, or extrauterine pregnancy, we mean those instances in which the fertilized ovum is arrested somewhere in its course from the ovary to the uterus and there undergoes development. Until as recently as 1883 the condition was of interest chiefly from its pathological standpoint; and few or even no cases were recognized clinically. But from that date, at which time Tait operated in his first case of ruptured tubal pregnancy, the clinical interest in the affection has been markedly increasing, as is shown by the decided increase in the literature on the subject and the apparent increase in the frequency of the condition.

FREQUENCY.—Before extrauterine pregnancy came to be recognized clinically and at autopsy, observers were much misled as to its frequency; and consequently such statements as that made by Hennig in 1876 to the effect that the affection is so rare that the directors of large obstetrical clinics might never see a case of it, were not to be wondered at. On the other hand, the data now available might readily lead one to suppose that the frequency has markedly increased since that time. Thus, for example, Parry in 1876 was able to collect only 500 cases that had been reported up to that time, while in 1892 Schrenck collected 610 cases which had been reported in the five previous years.

This apparent increase in frequency has also been noted in the experience of individual operators and in single clinics. The increase, as a matter of course, is more apparent than real; it is due unquestionably to our improved methods of diagnosis and greater knowledge of the subject.

ETIOLOGY.—So many theories have been advanced to explain the occurrence of ectopic gestation that it is impossible to make any very definite statements as to its etiology. J. Whitridge Williams, after a most exhaustive review of the literature, gives the following classification, which, although somewhat complicated, is probably the best which, in the present state of our knowledge, can be offered. He divides the etiological theories into four groups:

I. *Conditions which Interfere Mechanically with the Downward Passage of the Ovum.*—(*a*) Peritoneal adhesions. This is one of the earliest explanations for the occurrence of ectopic gestation and is still held by many to be the principal one. The adhesions act either by directly compressing the lumen of the tube, or by interfering with its muscular action; both of which conditions are sometimes verified at operation or at autopsy.

(*b*) Tubal polypi, projecting into the cavity of the tube and therefore impeding the downward passage of the ovum, have been found by certain operators. Williams in his analysis is of the opinion that only a few of the cases in which this condition was stated to have been the cause are at all convincing, and he agrees with Ahlfeld in thinking that in many cases the "tubal polypi" are merely decidual ingrowths, the result rather than the cause of the extrauterine pregnancy.

(*c*) Tumors of the tube wall and in some instances tumors of adjacent organs have been said to play a similar part by compressing the lumen of the tube.

(*d*) Salpingitis. The suggestion was made by Schroeder and Tait that inflammation of the lining of the tube so damaged the cilia of the mucous membrane that a downward current was no longer produced and consequently no obstacle was offered to the entrance of the spermatozoon into the tube. This view presupposed that fertilization normally took place in the uterus and that the ciliary currents favored a meeting of the male and female cells at the fundus. We know now, however, that the currents throughout the uterotubal tract run in the same direction, viz., from above downward, that the spermatozoon has to work against the stream from the time it enters the internal os, and that as fertilization normally takes place in the tube all pregnancies are primarily tubal. Microscopic examination, furthermore, has not confirmed the view put forward by Schroeder and Tait, for in these cases of tubal pregnancy ciliated epithelium is usually found covering the mucosa.

(*e*) Obstruction by twin ova. The comparative frequency of the coexistence of ectopic and uterine pregnancy has led certain observers to suggest the possibility of the mutual interference of twin ova as a cause of tubal pregnancy.

(*f*) Fetal twisting of the tube. While the Fallopian tube in adult life is a comparatively straight canal, that of the fetus is a convoluted one. These convolutions may persist in adults, and may then stand in causative relation to certain forms of tubal disease, notably extrauterine pregnancy.

(*g*) Diverticula of the lumen of the tube. The occasional presence of these diverticula was demonstrated by Williams in 1891, and he at that time suggested that they might be shown to act as a causative factor in certain cases of tubal pregnancy. While he is still of the opinion that such a state of affairs *may* exist, he admits that he has been misled by some of his specimens in which he found the fertilized ovum lying outside of an apparently intact tubal lumen. Since Peters has demonstrated in the uterus that the ovum burrows down beneath the epithelium, which finally

closes to form an intact surface over it, there is reason to believe that the same thing occurs in the tube; thus explaining the fact that in early cases of tubal pregnancy the ovum may be entirely outside of the lumen of the tube.

(*h*) Puerperal atrophy of the tube. Dührssen has reported cases of extrauterine pregnancy which have occurred in an incredibly short time after labor, in some instances even while the mothers were nursing their children. In these instances he considers the cause to be a puerperal atrophy of the tube which interferes with its peristalsis. In one case operated upon by the author this factor may have been present. The pregnancy probably began six weeks after the birth of a dead child, and tubal rupture took place six weeks later.

(*i*) External migration of the ovum, which is quite a common occurrence in extrauterine pregnancy, has been given as a causative factor by some investigators, they holding that the fertilized ovum in its transit through the peritoneal cavity attains such a size that its transmission through the opposite tube is an impossibility.

II. *Abnormal Conditions Resulting from Inflammatory Diseases of the Tubes, Ovaries, and Pelvic Peritoneum.*—Mention has already been made of the part that the absence of cilia is supposed to play in the causation of extrauterine pregnancy and little need be added to this statement. Most cases of tubal pregnancy will reveal a history of preexisting inflammatory trouble, and it is the rule to find some other abnormality besides the pregnant tube at operation or autopsy. This has given rise to the statement that an inflammatory condition of the pelvic organs is the principal cause of extrauterine pregnancy, but, unfortunately for the correctness of this statement, actual examinations at operation or at autopsy show that such an inflammatory condition is not present in all cases. On the other hand, the fact that tubal pregnancy occurs repeatedly in women suffering from gonorrhea certainly favors the above statement.

III. *Physical and Developmental Conditions which Favor Decidual Formation in the Tubes.*—This theory was originated by J. C. Webster, who was not satisfied with the numerous etiological views that had been advanced. He recalls the fact that as the uterus and tubes are both developed from the same embryonic structure, the Müllerian ducts, there is no reason why the ovum should not be implanted upon the upper as well as upon the lower portion of the tract. Normally, the lower portion of this duct becomes differentiated from the upper, so that in the latter the conditions are not such as to favor the formation of a decidua. Abnormally, on account of some developmental anomaly or reversion to an earlier type, the condition of the tubal mucosa is such that a decidua can form, and in such instances we can get an extrauterine implantation of the ovum. This view has been adopted by a number of observers, but, as is readily seen, it is based upon a theoretical rather than upon a practical basis.

Other observers, among whom may be mentioned Moericke and Fehling, have elaborated Webster's idea in that they claim that the occurrence of extrauterine pregnancy is a reversion to an earlier type, brought about by poor hygienic conditions. The former authority, basing his conclusions upon a large number of gynecological patients who were under his care in Chile, states that extrauterine pregnancy is a very rare occurrence among them, whereas at the Clinic in Stuttgart it was observed quite frequently. He attributes this marked difference to the fact that the Chilian women lead an outdoor life, while those of Stuttgart are subjected to very poor hygienic surroundings.

External migration of the ovum, the frequency of which in ectopic gestation has already been referred to, has led Sippel to put forth a view that is more or less closely allied to that of Webster. Sippel claims that it is necessary for a certain length of time to elapse between fertilization and decidual formation. Thus, when external migration occurs, the ovum is delayed in reaching the genital tract, and then finds in the tube conditions favorable for the formation of a decidua. This view is an interesting one, but is purely theoretical.

IV. *Conditions of the Ovum which may Favor its Arrest in the Tube.*—Some time ago, when the general opinion was that the uterine and tubal epithelium was converted into syncytium, Strassman was of the opinion that as the ovum entered the tube covered by the cells of the membrana granulosa, it could not become attached to the syncytium of the tube until this layer of granulosa cells had disappeared; but if the layer of granulosa was diminished in amount, or if for any reason it was absent, the naked ovum came into direct contact with the syncytially changed tubal mucosa and there became attached, while normally the layer of granulosa prevented this occurrence until the ovum had reached the uterus. This view is no longer tenable, for opinion is now unanimous that the tubal and uterine epithelium does not undergo this change—*i.e.* into syncytium—but that the latter is derived from the fetal ectoderm.

It is therefore very evident that there is no lack of theories as to the causation of extrauterine pregnancy. The mechanical theories must be given a certain amount of consideration, but they are open to the objection that while mechanical obstacles are frequently present, the existence of extrauterine pregnancy is of comparative rarity. On the other hand, recent experimental work on animals—ligation of the tubes and uterine cornua—has failed to cause extrauterine development of the ovum, after the animal under consideration has been put to the male. Thus these experimenters believe that the supposed extrauterine pregnancy in the lower animals is really uterine, the mistake being due to confounding the tubes and uterine horns with one another. Tubal diverticula may play an important part, and in some cases undoubtedly exist; but this again cannot hold good for all cases. The same may be said of inflammatory conditions.

We had best close this portion of the subject by quoting from Williams, who summarizes as follows: "The etiology of extrauterine pregnancy is not a simple matter, and there is no universal cause for all cases. Careful study of the specimen and of the patient's history will give us a satisfactory explanation for its occurrence in the majority of cases, but in a small number we cannot account for the production of the affection, and its cause will remain to us as great a problem as to our predecessors."

Classification.—The fertilized ovum may be arrested at any point between the ovary and uterus We may thus distinguish between ovarian and tubal pregnancy according as the development occurs in either of these organs. To these two forms some add a third, viz., abdominal pregnancy; but there is considerable doubt as to whether a primary implantation can take place on the peritoneum and thus give rise to this form of pregnancy.

Ovarian Pregnancy.—Ovarian pregnancy was first described early in the seventeenth century, and in the eighteenth was pretty generally recognized. In 1835 Velpeau made the statement that many of the cases described as ovarian pregnancy were open to objections, and he took the rather radical view that none of the cases reported gave to him conclusive evidence as to their ovarian origin. Observers in general agreed with him, and at present there are few who believe in the existence of ovarian pregnancy.

There is evidence, however, that the condition undoubtedly does exist, although very rarely; and, since

Spiegelberg reported a case of this nature in 1878, we are in possession of certain criteria by which an ovarian pregnancy can be recognized. Spiegelberg demands that the following conditions be noted before we can make a diagnosis of a given ectopic gestation being ovarian: (1) The tube on the affected side must be intact. (2) The fetal sac must occupy the position of the ovary. (3) It must de connected with the uterus by the uteroovarian ligament. (4) Definite ovarian tissue must be demonstrated in its walls. When judged by these criteria it is clearly seen that many of the cases reported as ovarian pregnancy will be found wanting. Williams, in discussing these points brought out by Spiegelberg, calls attention to the fact that in certain cases of tubal and broad-ligament pregnancy, the ovary may be so flattened out as apparently to occupy a portion of the sac wall, and for this reason he suggests that the fourth condition be so modified as to read: "Definite ovarian tissue must be demonstrated, not at a single point in the sac wall, but at several points a considerable distance from each other."

Williams has carefully reviewed the literature of ovarian pregnancy in the past hundred years and has applied the above criteria to the reported cases. The results of his analysis show that only four cases can be classified as *positive cases*, eleven cases as *highly probable*, and twenty as *fairly probable;* thus clearly demonstrating that, although ovarian pregnancy undoubtedly does exist as a primary condition, it is of the greatest rarity. He also shows that one-half of the positive or probable cases reached full term, indicating that the ovarian tissue can more readily accommodate itself to the increase in size of the growing ovum than can the tube.

In ovarian pregnancy rupture with formation of a secondary abdominal pregnancy can occur, or the case may go to term and the formation of a lithopedion be the result.

Tubal Pregnancy.—When the ovum is arrested in the Fallopian tube and develops there, we have what is known as a tubal pregnancy; this is by far the most frequent variety of extrauterine pregnancy. According as the arrest of the ovum occurs in the various portions of the tube we can distinguish between ampullar, isthmic, and interstitial pregnancy, the relative frequency being in the order named.

Tait's idea was that the invariable fate of a tubal pregnancy was rupture into the peritoneal cavity, and that this rupture always occurred not later than the twelfth week. Further investigation, however, has proven this view to be an erroneous one, and that many cases terminate at a much earlier period, in what is known as tubal abortion, or that in rare instances the tube may so accommodate itself to the growing ovum that the case may go on to term.

Tubal abortion was thought to be, until quite recently, a pathological curiosity, but in 1887 Werth called attention to the fact that it was not infrequent for the ovum to be extruded through the fimbriated end of the tube into the peritoneal cavity. Attention having been directed to the fact, it is now generally believed that this is the most frequent termination of tubal pregnancy, and statistics collected by Martin, Orth, Mandl, Schmidt, and others show that seventy-eight per cent. of the cases end in tubal abortion as against twenty-two per cent. rupturing into the peritoneal cavity. Martin indeed considers that abortion is the general rule and says that rupture occurs only in those cases in which abortion is prevented by closure of the fimbriated end of the tube.

The abortion which occurs in the tube is in a measure analogous to that which takes place in the uterus. The liability to hemorrhage is increased owing to the imperfect development of the decidua. The maternal vessels are opened up by the downgrowth of fetal ectoderm or trophoblast, and the hemorrhage loosens the embryo from its attachment to the tube wall. If the separation is complete, the ovum is forced through the fimbriated extremity and the abortion can be designat d as "complete." On the other hand, if the separation of the ovum is only partial, the hemorrhage continues and the ovum remains in the tube; here the abortion is "incomplete."

It is probable that two factors act in the expulsion of the ovum—viz., the actual contraction of the muscular walls of the tube, and the force from behind furnished by the blood clot. If the abortion is complete, hemorrhage will be profuse; but if the ovum remains in the tube, it may be converted into a "fleshy mole," similar to those observed in uterine abortions.

What has been just gone over has served markedly to change the views that were formerly held as to the causation of pelvic hematocele and hematosalpinx. Opinion is now pretty general that both of these conditions are secondary results of tubal pregnancy. In the first instance the blood flowing through the fimbriated end forms a clot in the neighborhood of the ovary, and in the second the hemorrhage occurs into the tubal lumen and the blood remains there.

Rupture into the Peritoneal Cavity.—As has already been stated, rupture in this manner is not so common as was thought by Tait. When it does occur the pregnancy is usually situated at some distance from the fimbriated end of the tube—either at the isthmus or in the interstitial portion. If it is situated at the isthmus, rupture usually takes place within the first twelve weeks of the pregnancy, and not infrequently during its first month; but if it is situated in the interstitial portion rupture occurs later, for this portion of the tube, being surrounded by uterine muscularis, more readily responds to the influence of pregnancy and allows the ovum to attain a larger size.

Rupture may occur spontaneously or may be brought about by violence; the most frequent form of violence being a rough vaginal examination. The writer recalls a case in charge of a friend in which death from hemorrhage took place twelve hours after a vaginal examination; the diagnosis of extrauterine pregnancy had not been made. When rupture occurs spontaneously it usually follows some exertion on the part of the patient.

The underlying causes of rupture are twofold, viz., (*a*) overdistention of the tube by the growing ovum and (*b*) perforation of the tube wall by the chorionic villi, which grow down rapidly between the muscle fibers and not infrequently penetrate to the peritoneal coat. The fetal ectoderm or trophoblast proliferates and causes a certain amount of degeneration of the muscle fibers and connective tissue of the tube wall. If then, as frequently happens, a maternal blood-vessel be opened, the rapid discharge of blood into the tube will cause its overdistention and rupture.

Rupture usually takes place in the neighborhood of the placental site, and hemorrhage and discharge of the ovum will occur either into the peritoneal cavity or between the folds of the broad ligament, depending on the original site of implantation of the placenta.

When rupture occurs into the peritoneal cavity, as a rule the entire ovum is extruded; but if the wound be a small one, there may be profuse hemorrhage without the ovum being discharged. In either case, however, the hemorrhage is profuse and the patient will show marked signs of collapse—or will die before relief can be obtained. In the event of an operation or if a fatal issue should not take place, the result will depend upon the amount of damage which has been done to the ovum.

If the entire ovum escapes into the peritoneal cavity its death is inevitable, and, unless the fetus is beyond the third month, absorption of the entire product of conception is the rule. The old view that in such a case the placenta may become attached to some neighboring organ and thus form vascular connections is now scarcely tenable; but if the fetus alone escape

from the tube and the placenta remains *in situ*, the effect of the rupture on the pregnancy will vary according to the amount of damage done to the placenta. In those cases in which the greater portion of the placenta remains attached, the fetus will go on to term as a secondary abdominal pregnancy, and if the original tubal wound has been a small one the placenta will develop in a sac formed by the remains of the tube; but if the rent were large and close to the margins of the placenta, this organ will overgrow its tubal attachments and become adherent to some neighboring organ, viz., uterus, pelvic floor, or intestines. Most observers agree that further growth of the fetus after escape from the tube is impossible unless it is surrounded by the amnion. There are, however, exceptions to this rule.

Rupture between the folds of the broad ligament takes place in a few cases through that portion of the tube wall which is not covered by peritoneum, and here the tubal contents will pass downward into that space which is situated between the broad ligament and its peritoneal covering. This is considered the most favorable termination of an extrauterine pregnancy and usually results in the death of the ovum and the formation of a broad-ligament hematoma. More rarely the pregnancy may go on to term in this situation; and in such a case it is evident that the placenta, being attached to the unruptured portion of the tube wall, will lie at the superior part of the gestation sac, which condition has given rise to the erroneous idea that the placenta may be attached to some remote organ such as the liver or the diaphragm. In such a case the pregnancy is entirely outside of the peritoneal cavity, and the condition has been spoken of as a broad-ligament or extraperitoneal pregnancy. The gestation sac here has been known to rupture, and a secondary abdominal pregnancy is then the result.

The intimate relation that exists between these pregnancies and the rectum renders them more prone to invasion by intestinal bacteria, and if suppuration should occur the proximity to the bladder explains the discharge of fetal bones, etc., by way of the urethra —an occurrence which has been noted in such instances.

Williams and others are of the opinion that the frequency of this form of pregnancy has been overestimated, as Williams has observed it only once in about forty cases.

Abdominal Pregnancy.—There is at present little doubt in the minds of most operators that those cases which were thought to be primary abdominal pregnancies have turned out to be only secondary abdominal pregnancies, *i.e.* secondary to a preexisting tubal pregnancy, and there is uncertainty as to the possibility of the existence of a pregnancy primarily abdominal. Recent work by Zweifel, Martin, and others, has shown that the fertilized ovum can become implanted upon that thin strip of tubal tissue which extends from the fimbriated extremity of the tube to the ovary, the fimbria ovarica. It is readily seen, however, that such cases are not abdominal but in reality tubal in origin, which, when we bear in mind the fact that small structures covered by ciliated epithelium have been found in the wall of the gestation sac of many cases described as primary abdominal pregnancy, materially weakens the theory as to the possibility of such a form of extrauterine pregnancy existing. If, for example, an ovum became implanted upon this portion of the tube, the placenta would very rapidly overgrow the very narrow limits of the fimbria ovarica and give one the impression that the pregnancy were primarily abdominal. Williams, in his discussion of this part of the subject, says that, of the cases thus far described, not a single one appears to him to furnish sufficient evidence to justify its being considered primarily abdominal. Nevertheless, in view of the fact that decidual formation has been noted in the subperitoneal connective tissue, the possibility of such a thing cannot be denied.

Fate of the Fetus in Extrauterine Pregnancy.—Attention has already been called to the fact that when small embryos are extruded into the peritoneal cavity absorption is the rule. This fact is made manifest by the circumstance that one rarely succeeds in finding any trace of the fetal body in the blood clots which fill the peritoneal cavity after tubal rupture. Absorption frequently takes place within the gestation sac inside of the tube, and when we cut into such a tube it is by no means unusual to find a shapeless mass hanging to the umbilical cord, or even no trace of embryonic body at all, while the cord simply hangs free in the amniotic cavity.

Such a termination, however, is impossible when the fetus has reached a certain size; it then undergoes one of the following changes: mummification, suppuration, conversion into a lithopedion or into adipocere. In the first of these conditions the fluid portions of the embryo are absorbed and the fetus becomes converted into a dry, mummified mass, nothing remaining but the bones, covered by a shrivelled skin. When suppuration takes place, as is quite common in cases of broad-ligament pregnancy, the sac first suppurates and the process then extends to the fetus. The patient, under these circumstances, shows marked signs of sepsis, and, unless the pus is evacuated by operation or by rupture, she will die. Rupture into the bladder or rectum is not an uncommon termination in such instances.

In a small number of cases neither of the above changes takes place, but the fetus and membranes, by a deposition of lime salts within them, become converted into a calcareous mass or lithopedion. A structure of this character has, in certain instances, been carried by the mother for years, giving no trouble except when it blocks the pelvis and forms an obstacle to normal labor. Küchenmeister has carefully reviewed the literature of this portion of the subject and divides lithopedia into three classes: (1) Calcification limited to the fetal membranes (lithokelyphos); (2) both fetus and fetal membranes partially calcified (lithokelyphopedion); and (3) calcification limited entirely to the fetus (lithopedion).

The last possible termination—conversion into adipocere—occurs only rarely. Here the fetus is transformed into a greasy yellow mass; the material is thought to be an ammoniacal soap.

Anatomical Considerations.—*Sac Wall.*—In early unruptured tubal pregnancy, the tube is the seat of a fusiform swelling about one or two centimeters from its uterine end. Sections through a pregnancy at this age show that the sac wall is made up of the muscularis of the tube. The individual muscle cells, however, do not seem to be increased in number but spread apart by edema. There is marked dilatation of the arteries and veins in this situation, particularly in the neighborhood of the placental site, and there may be some hemorrhage into the lumen of the tube. Later, one will notice marked degenerative changes in the tube wall in the neighborhood of the chorionic villi, so that at this period the sac wall consists of a tissue closely resembling fibrin. The thickness of the tube wall diminishes as the pregnancy advances, and the muscular elements appear to have diminished in number. If the case reach term the sac wall will be found to be composed almost entirely of connective tissue with here and there a muscle fiber, indicating that the muscularis of the tube has not the same tendency to proliferate under the influence of pregnancy as has that of the uterus.

It is not possible to make definite statements as to the part played by the ovary in the formation of the sac wall of an ovarian pregnancy. The diagnostic value of the presence of ovarian tissue in the sac wall

of pregnancies thought to be ovarian has already been referred to, and it is evident that positive statements cannot be made as to the ovarian origin of the pregnancy unless ovarian tissue can be demonstrated in several parts of the sac wall more or less remote from one another.

The condition of the fimbriated end of the tube varies: if tubal abortion has taken place, it is of course patent; while if abortion has not occurred it may or may not be opened. The relation of the lumen of the tube to the pregnancy is also a subject of variation. In certain instances it can be traced into both ends of the fetal sac, while in others it is apparently completely shut off.

Decidua.—It has long been known that the uterine mucosa under the influence of extrauterine pregnancy becomes converted into decidua just as it does in uterine pregnancy, and it was formerly held that its structure is the same under both conditions. However, observers such as Williams, Dobbert, and Tussenbroek have pointed out that there exist certain differences in the structure of the two membranes. For example, in uterine pregnancy the spongy layer of the decidua is not so well developed as in extrauterine pregnancy, and in the former there is a portion of decidua lying under the spongy layer that maintains the appearance of the normal, non-pregnant mucosa. In extrauterine pregnancy the vessels are markedly enlarged and lie near the surface of the decidua, their rupture accounting for the uterine hemorrhage so frequent in this condition.

Decidua Vera in the Tube.—The opinion of all of the earlier writers on extrauterine pregnancy was that a definite decidua vera was developed in the pregnant tubes. In 1891 Bland Sutton denied its existence, and since then there have been many conflicting statements regarding it. If one expects to find a distinct decidual membrane in the pregnant tube analogous to that found in the uterus one will be disappointed, as it does not occur as such; but beyond any possible doubt changes take place in the connective-tissue stroma cells of the tubal folds by which they are converted into cells morphologically similar to the decidual cells in the uterus. This change does not take place throughout the entire length of the tube, but only in discrete patches, and undoubtedly a great part of the tissue which has been described as decidual is in reality fetal ectoderm. The view that a decidua forms in the tube has been materially strengthened by the discovery of analogous changes in the opposite non-pregnant tube, so that at present we cannot deny that a decidua vera is formed, although not to the same extent as in the uterus. Williams has shown that the columnar epithelium of the tube becomes flattened out just as it does in the uterus.

Decidua Serotina and Reflexa.—From what has just been said, it is evident that the decidua serotina does not reach the same state of development in the tube that it does in the uterus, and undoubtedly that which has so frequently been described as serotina is nothing more than a mass of fetal ectoderm or "Zellschicht." Careful examination, however, at the point of attachment of the ovum will enable one to differentiate between three varieties of cells, viz., syncytium, "Zellschicht," and true decidual cells.

The same may be said of the reflexa—*i.e.* while undoubtedly present it never reaches the same stage of development that it does in the uterus. Its existence has been denied by many, but if one examines a carefully prepared intact specimen, one finds a thin layer of tissue separating the ovum from the lumen of the tube. This band of tissue is usually covered on its outer side by flattened tubal epithelium; it contains few if any true typical decidual cells. The cells in this situation can be identified with "Zellschicht" cells, and as pregnancy advances marked degenerative changes in them are seen to occur.

Placenta.—Except for the difference in the structure of the tube wall and uterus, and the difference in the formation of the decidua, the structure of the placenta in tubal pregnancy does not differ materially from that in uterine pregnancy. The chorionic villi, not being separated from the muscularis and vessels by a thick layer of serotina, invade more deeply and quickly the tube wall and open up the vessels, thus accounting for the hemorrhage and early tubal abortion. The villi themselves present practically the same appearance in extra- as in intrauterine pregnancy, their stroma is made up of a loose mucoid connective tissue, and in early cases one can distinguish two layers of epithelium—"Zellschicht" and syncytium. When a villus comes in contact with the serotina its behavior is the same in the tube as in the uterus; viz., there is marked proliferation of the "Zellschicht" at the point of contact, resulting in the formation of a "cell node." If abortion does not occur at an early period, a definite intervillous circulation is established, the intervillous spaces being lined with syncytium just as in uterine pregnancy.

Symptoms.—The symptoms of an early unruptured extrauterine pregnancy are by no means characteristic, and frequently one has no idea of the existence of the condition until rupture takes place and the patient is in a state of collapse.

The patient usually considers that she is beginning an ordinary uterine pregnancy, and has the usual subjective symptoms of that condition. There is not uncommonly some pain in one or the other ovarian regions, but usually so slight as not to alarm either the patient or her friends. Menstrual suppression, while not the rule, sometimes occurs. Statistics show that the menses persist in about forty-three per cent. of the cases.

If the fetus dies at an early period—*i.e.* before rupture or tubal abortion—there is usually a discharge of blood from the uterus. This may be mistaken for the return of a delayed menstrual period or an early abortion.

In the majority of cases the first indication of anything being wrong is the occurrence of a sharp, lancinating pain in the ovarian region, followed soon by signs of collapse. When collapse occurs it is usually the result of intraperitoneal hemorrhage, either from a rent in the tube wall or from the fimbriated extremity after tubal abortion, and it is readily seen how, unless immediate relief be obtained, the collapse may become deeper and deeper and the individual finally bleed to death into her peritoneal cavity. On the other hand, the hemorrhage may not be of sufficient extent to be fatal, and here the result will be a retrouterine hematocele.

If the hemorrhage is severe the symptoms are those of collapse—weak, rapid pulse, subnormal temperature, pallor, etc.—while in those cases in which the hemorrhage is slight and is followed by the formation of an hematocele, we have a general improvement of the symptoms. The present opinion is that by far the majority of pelvic hematoceles are the result of an extrauterine pregnancy.

Hematocele usually is the result of tubal abortion and not of tubal rupture, and according as the hematocele occupies the greater part of the pelvis or forms a smaller mass in the region of the fimbriated end of the tube, we can differentiate between diffuse and solitary pelvic hematoceles. In the former case adhesions of the pelvic viscera are necessary to prevent the escape of the blood into the general peritoneal cavity, but not in the case of the latter, for according to Sänger the solitary hematocele is the result of a gradual dripping of blood from the fimbriated end of the tube. The formation of an hematocele is almost always a favorable termination for extrauterine pregnancy, for in this way the acute hemorrhage is checked. However, cases have been reported in which the hem-

orrhage at the center of the mass continues, finally causing its rupture into the peritoneal cavity and death. Another unfavorable termination of hematocele is suppuration.

Occasionally the patient does not succumb to the first loss of blood, and here, if the placenta is not entirely separated from its attachment to the tube wall, a secondary abdominal pregnancy will result. In such a case the ordinary symptoms of pregnancy will continue, possibly with an abnormal amount of pain.

In a small number of cases rupture may occur between the folds of the broad ligament, and further development go on only to rupture again into the peritoneal cavity; then the fetus becomes abdominal while the placenta remains between the folds of the broad ligament. Term may be reached in such an instance.

When a patient with a secondary abdominal pregnancy reaches term, what is known as false or spurious labor sets in, during which there are distinct contractions similar to those occurring in the early stages of normal labor. The contractions, however, are not of the gestation sac, for this structure contains so few muscle fibers that its contraction is a matter of impossibility; but the contracting organ is the uterus. False labor continues for several days and during that time the child dies. After fetal death the placental circulation becomes obliterated; the fetal sac shrinks and becomes closely applied over the body of the child, which then undergoes one of the changes above mentioned. The abdomen here of course becomes smaller, a symptom which is usually noticed by the patient.

In certain instances the extrauterine pregnancy may exist at the same time as an intrauterine one. Parry pointed out the frequency of this occurrence and found that it occurred twenty-two times in 500 cases. Parry called the conditions "combined pregnancy." More rarely twin extrauterine pregnancy has been noted, and in very rare cases both fetuses were in the same tube.

Repeated tubal pregnancy has been observed and reported in a number of instances. Williams has collected a total of sixty-six such cases in which the diagnosis has been confirmed at operation or autopsy. This phenomenon has been utilized by certain observers to explain points in the etiology of the affection. The anatomical findings, however, have not been uniform, and little information has been gained from this source.

Diagnosis.—The symptoms of an early unruptured extrauterine pregnancy are so uncertain that they render a diagnosis at this stage almost an impossibility. Tait made the statement that it was impossible to make a diagnosis, and most operators agree with him. In rare cases a diagnosis of the condition is made, but it is almost the rule that after such a diagnosis the operator finds the mass in question to be either an inflamed tube or a small ovarian cyst.

The diagnosis would be based upon the following symptoms: A patient who had been sterile for some time thinks herself pregnant, having the usual subjective symptoms, with possibly an abnormal amount of pain in the ovarian region. If such a patient were the subject of a tubal pregnancy, on examination the uterus would be found to be enlarged and somewhat soft and boggy, and off to one side there would be a small pulsating (?) tumor roughly the size of the supposed pregnancy. But as has already been said, it is common to find after such a diagnosis (?) that the mass is of other than the suspected nature. Taylor has called attention to the fact that the pregnant tube may prolapse into the cul-de-sac of Douglas and give one the impression of a retroflexed pregnant uterus—a statement proven by the fact that several cases have been reported in which rupture of the tube followed an attempt to replace that which was thought to be the fundus.

According to Williams, Veit in Germany in 1883 and Janvrin in this country in 1888 were the first to confirm by abdominal section the diagnosis of unruptured tubal pregnancy. This state of affairs is very rare, the writer never having seen a case in a considerable experience as resident obstetrician in the Johns Hopkins Hospital, and he knows of only one case in the hands of a colleague (Upham of Columbus, Ohio).

If the fetus die before rupture of the tube a diagnosis is still very difficult, such cases usually being taken for uterine abortion associated with an inflammatory tubal mass. The source of error is that when the fetus dies the uterine decidua is cast off in shreds giving the appearance of the discharge of a normally implanted ovum.

Most observers believe that the discharge of a more or less complete decidual cast of the uterine cavity is an infallible sign of extrauterine pregnancy. The fallacy of this sign is shown, however, by the fact that, relying on this sign alone, some operators (Griffith and Dolan) have opened the abdomen only to find it free from abnormality, or that the supposed extrauterine pregnancy had been simulated by a small ovarian cyst.

It has been advised that the uterus be curetted for diagnostic purposes, the presence of decidua on the scrapings affording conclusive evidence as to the existence of extrauterine pregnancy; but as the decidua may have been cast off early in the pregnancy, the discharge being considered by the patient to be a menstrual period, the uncertainty of this procedure is obvious.

At the occurrence of rupture or of tubal abortion with intraperitoneal hemorrhage, the symptoms are so characteristic that an almost certain diagnosis can be made even without an examination. The patient may or may not have given the above history when suddenly, with a sharp attack of pain in the ovarian region, she goes into a condition of collapse, with weak rapid pulse, pallor, subnormal temperature, etc. Vaginal examination here usually reveals but little, as the patient is too sensitive to allow a thorough exploration. A crepitating sensation may be imparted to the examining finger in the cul-de-sac, due to pressure upon recently clotted blood. With the above symptoms the diagnosis of ruptured tubal pregnancy is practically a certainty, and if not speedily relieved by operation the patient will die. If she recover from the collapse the probabilities are that a tubal abortion has taken place and that the hemorrhage has been checked by the formation of a pelvic hematocele.

As tubal rupture may occur very early in pregnancy, even before the patient has thought herself pregnant, one should always regard collapse with signs of intraperitonal hemorrhage as strong probabilities in favor of ruptured extrauterine pregnancy; and in such a case only by acting promptly can the life of the patient be saved.

If, as is often the case, she is not seen until after primary rupture, examination will reveal a large tumor filling the posterior portion of the pelvis, and an exploratory puncture through the posterior vaginal fornix will render the diagnosis certain.

In cases in which the fetus has survived the damage done at the time of primary rupture and has continued to develop in the abdominal cavity or in a gestation sac, the diagnosis is not usually made, because attention is not directed to the fact of early rupture, and it is not until false labor sets in that our suspicions arise as to the child's not being in the uterine cavity. If careful examination be made, however, the condition should offer little difficulty; the child is found to be more easily palpable than normal, its movements give the mother a certain

amount of pain, and by bimanual examination the uterus is found to be practically normal in size. If an hematocele has formed between the folds of the broad ligament, the mass will lie largely in the small pelvis and the uterus will be pushed over to one side.

When an extra-and an intrauterine pregnancy occur together and have reached term, the diagnosis of twins has usually been made, and it is not until the cause of delay in the birth of the second child is investigated that its extrauterine existence is noted.

TREATMENT.—*Before Rupture.*—When an extrauterine pregnancy is diagnosed before rupture, it must be regarded as a malignant growth and removed by laparotomy as soon as possible. This procedure cannot be too urgently advised, for until it is removed the patient is in imminent danger of a fatal rupture. All methods which have as their end the destruction of the fetus, such as electricity or the injection of medicinal substances, are to be strongly condemned; for, as we know, even the death of the child does not preclude the possibility of rupture of the tube. However, from what has already been said, it is apparent that such a line of treatment will rarely be thought of owing to the uncertainty of diagnosis at this time.

After Rupture.—The diagnosis of ruptured tube and intraperitoneal hemorrhage once having been made by the characteristic symptoms already discussed, the abdomen must immediately be opened (unless the degree of collapse is so great that the patient is moribund when first seen). Then immediately afterward long clamps are to be passed down into the pelvis and applied on both sides of the tubal mass. This will at once check all hemorrhage, and the injured tube can be excised without unnecessary haste. If the peritoneal cavity is filled with clotted blood which obscures the field of operation, the clamps must be applied by the sense of touch alone.

The loss of blood may call for the infusion of physiological salt solution. This can be done during the operation and the infusion allowed to run into the submammary subcutaneous tissue or injected directly into the circulation.

Operation through the vagina has many obvious disadvantages and is mentioned here only to be condemned. Among the disadvantages may be mentioned the small field of operation in the vaginal method as compared to the large one in the abdominal, and the frequent necessity of having to open the abdomen to arrest hemorrhage which has been started in the vaginal operation.

Hematocele.—It has been shown that the majority of cases of pelvic hematocele undergo spontaneous cure and rarely require operation. Thorn reports 157 cases, in only six of which was operation thought necessary, the rest having been treated by careful watching and rest in bed. The total mortality here was only six-tenths of one per cent. Fehling has reported ninety-one cases, treated in a similar manner, without a single death. A disadvantage of the method, however, is that it is extremely slow and the patients have to remain many weeks in bed.

On the other hand, there are certain condition which render operation imperative in cases of hem atocele: such indications as rapid increase in the size of the tumor, signs of suppuration, or pressure on important organs. When such conditions are present the hematocele is best attacked by way of the vagina. An incision is made through the posterior vaginal wall, the clot is evacuated, and the cavity is at once packed with sterile gauze. This usually gives most excellent results, but all operators agree that it is frequently necessary to open the abdomen in order to check hemorrhage that cannot be controlled by the pack; therefore one should always have the abdomen prepared for a laparotomy before making the vaginal incision.

Treatment during the Later Months of Pregnancy.—Occasionally in the latter half of pregnancy we shall find the fetus enclosed in a large tubal or ovarian sac; more commonly, however, the fetus has escaped through the rent in the tube wall and we have to deal with a secondary abdominal pregnancy in which the placenta is attached to the pelvic floor while the fetus lies free. In such cases, as there is always danger of a secondary rupture, prompt laparotomy is indicated. If the child is within a few weeks of viability some have advised a waiting policy, thus giving the child a chance that it would not have were immediate operation done. If such a course be decided upon the dangers to the mother should always be explained to the family.

As to the best method of operating in such cases, unquestionably the ideal procedure is to open the abdomen and remove the entire gestation sac; but frequently, on account of adhesions to neighboring organs, such a course is inadvisable, and here the sac should be incised, care being taken to avoid wounding the placenta if possible. Then the child should be removed and the edges of the sac should be stitched to the margins of the abdominal wound, the cavity being packed with gauze and the placenta allowed to come away piecemeal. This entails a longer convalescence, but on the whole is better than endangering the life of the patient by attempting to remove an adherent placenta. In certain cases this plan cannot be carried out, and then the entire sac must be removed no matter how serious the procedure may seem.

When the fetus dies the danger to the mother materially diminishes, for when the fetal circulation ceases, the hemorrhage from the placental site is not so much to be feared. If a diagnosis of the death of the child be made, operation should be deferred for a short time in order to favor closure of the maternal blood spaces and separation of the placenta; it being understood, however, that immediate operation may be necessary at any time. GEORGE W. DOBBIN.

Geuda Springs.—Cowley County, Kansas.

POST-OFFICE.—Geuda Springs. Hotel and boarding houses.

The Geuda Mineral Springs are located on the Midland Valley Railroad and the Kansas and Southwestern Railroad, one mile distant from the Arkansas River and eight miles north of Indian Territory. Geuda is an Indian term meaning healing water. The town of Geuda Springs is pleasantly situated at the edge of a beautiful and undulating plateau, which is everywhere dotted with fine farms and neat farmhouses. The elevation above the sea is about 1,400 feet, and the atmosphere is pure and wholesome. The winters are short and open, making constant outdoor exercise possible. There are very few hot days in summer, the thermometer rarely rising above 100° F., but, as a rule, the days are balmy and the nights cool and refreshing. Geuda Springs artesian mineral well flows a solid six-inch stream. The other springs are seven in number, and bubble up in a space ess than twenty feet square. Near the springs is a beautiful lake of salt water, with an area extending to the westward nearly two miles, and another to the southward nearly half that distance. The evaporation of the water causes the beach to be covered with pure, crystallized salt. This picturesque body of salt water, constantly fed by salt springs, furnishes fine advantages for bathing. The lake bottom is hard and sandy, and bathers can secure any depth of water desired. A commodious bath-house in connection with the springs affords opportunities for any variety of bath which may be desired. Following is a detailed analysis of the seven springs by Professor Bailey, of the Kansas State University:

NUMBER OF GRAINS IN EACH UNITED STATES GALLON OF 231 CUBIC INCHES.

	Spring No. 1.	Spring No. 2.	Spring No. 3.	Spring No. 4.	Spring No. 5.	Spring No. 6.	Spring No. 7.
Sodium chloride	1030.93	1056.28	815.68	671.76	357.05	432.20	504.21
Calcium sulphate	199.64	204.73	167.58	158.29	145.88	147.33	160.17
Magnesium sulphate	25.56	24.24	28.53	26.64	24.98	27.43	22.86
Magnesium chloride	16.55	19.96	10.01	7.90	8.45	4.95	9.66
Calcium bicarbonate	3.70	5.90	5.99	6.86	10.67	12.50	5.51
Potassium sulphate	12.12	1.69	1.90	1.90	.82	.54	.47
Sodium phosphate	.02	.02	.02	.02	.04	.08	.08
Sodium bromide	.02	.02	.01	Trace			
Sodium iodide	Trace		Trace				
Sodium biborate	.16	.16	.16	.08	.12	.12	.25
Sodium nitrate	.38	.40	.18		.02	.03	.03
Sodium bicarbonate	.41	.32	.39	.69	.49	.31	.60
Sodium sulphide						.65	
Lithium chloride	Trace	Trace	Trace	Trace	Trace	Trace	Trace
Iron bicarbonate	.07	.19	.07	.05	.03	.06	.08
Alumina	.06	.01		.01	.01		.01
Silica	.67	.86	.81	.79	.92	.73	.79
Organic matter	Trace	Trace	Trace	Trace	Trace	Trace	Trace
Total	1290.29	1314.78	1031.33	874.99	549.48	626.93	704.72
Free carbonic acid gas in cubic in.	34.96	27.69	18.32	17.64	23.98	22.16	29.05
Sulphureted hydrogen gas						Trace	Trace
Specific gravity	1.018	1.016	1.013	1.012	1.008	1.009	1.009
Temperature	63° F.	63° F.	63° F.	63° F.	63° F.	63° F.	63° F.

These waters may be classed as belonging to the muriated and sulphated-saline variety (carbonated). They have found their most suitable application in liver, kidney, and stomach disorders, general debility, anemia, and rheumatism. Some of the springs have gained considerable celebrity in the local treatment of conjunctivitis, indolent ulcers, leucorrhea, and other disorders. EMMA E. WALKER.

Geum.—See *Avens.*

Giant Cells.—The term giant cell is applied to certain normal and pathologic cells of great size. These masses of protoplasm may possess many nuclei (over 100 at times), or there may be one large regular, or an irregular lobulated nucleus. The giant cells are derived from the mesenchymal tissues and usually arise from the repeated divisions of the nucleus without the usual segmentation of the cytoplasm. Some writers hold that gaint cells arise from the fusion of endothelial or other connective-tissue cells; the possibility of their formation by the fusion of leucocytes must also be borne in mind. Giant cells represent elements of low organization, yet play an important part in normal and pathologic processes. An important property of giant cells is that of *phagocytosis*—that is the removal of small foreign particles that enter the body, or of dead and useless tissues that result from disease or injury. The leucocytes may fuse around the foreign particles or bacteria forming a *plasmodium*, or giant cell; this cell then digests the enclosed substance or separates it from the tissues rendering it innocuous. These giant cells may secrete a ferment that will dissolve dead or useless tissue so that in the liquid state, they may be carried away by the lymphatics and be eliminated from the system. This phagocytic action, especially of the leucocytes, has an important bearing upon immunity and recovery from infectious diseases.

As giant cells are found in normal and pathological processes, they will be considered under these heads.

NORMAL.—Under normal conditions, giant cells are found in certain tissues and organs as the bone-marrow, hemolymph nodes, lymph nodes, spleen, and liver.

Myeloplax.—In red bone-marrow is a large cell called the megacaryocyte, or myeloplax. It consists of a very large mass of granular protoplasm, containing, usually, a single large nucleus that might show divisions by its lobulation. The cytoplasm contains oxyphilic granules that, however, do not seem to be the same as those of leucocytes. According to M. Heidenhain, the protoplasm shows three distinct zones. He also states that each cell contains a number of nucleoli as well as a number of centrioles. These latter may be either grouped or scattered; if the nucleus be annular, the centrioles lie in a group within the ring. These cells are said to be ameboid, but not phagocytic and are to be found in other erythrocyte-forming organs.

FIG. 2787.—Giant Cell of the Bone-marrow, Showing Multiple Centrioles at *f*; *a*, *b*, *c*, *d*, represent the different zones of protoplasm; *e*, nucleus. (After M. Heidenhain.)

Osteoclasts.—In the marrow of growing bones as well as upon the surface of adult bones is seen a specific form of giant cell called *osteoclast*. Such a cell is somewhat similar in appearance to the preceding. It is spheroidal or flattened, but the cell outline is regular and the granular protoplasm contains two to ten or more, clear, round nuclei. The side of the cell attached to the bone is often striated. These cells are numerous in developing bone where bone

absorption is active. In finished bone, they are seen lying in small depressions (*Howship's lacunæ*) upon the surface beneath the periosteum. They are also found in connection with the roots of the milk teeth that are undergoing absorption and in the repair and tumors of bone.

In *hemolymph nodes* giant cells with large lobulated nuclei, similar in appearance to those of bone-

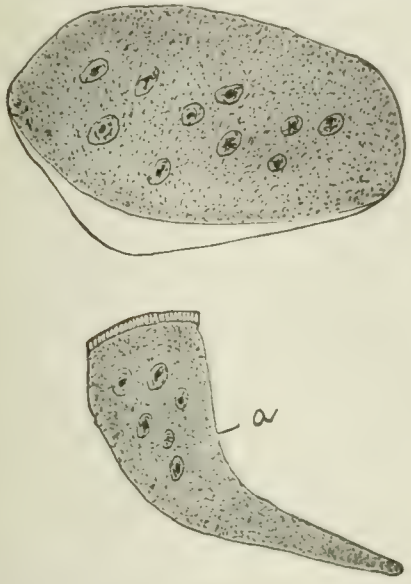

Fig. 2788.—Osteoclasts from Growing Bone. *a*, Shows a striated border. (After Kolliker.)

marrow, are seen. They seem to have to do with the formation of erythrocytes. During fetal life and in young animals similar giant cells are found in the *liver* and in the *spleen;* while their function is not known, they are supposed to be connected in some way with the formation of erythrocytes.

Pathological.—Giant cells seem to occur more frequently in pathological conditions.

Tuberculosis.—In tuberculosis these cells are quite characteristic. They are large masses of protoplasm

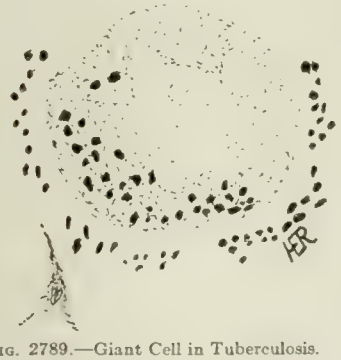

Fig. 2789.—Giant Cell in Tuberculosis.

that often contain a hundred nuclei. One view of their origin is that they arise by repeated division of the nucleus without a corresponding division of the protoplasm. They appear during the active cell proliferation caused by the presence of the tubercle bacilli and often contain these bacilli in the cytoplasm, which fact points to their phagocytic property. This fact points also to another view as to their origin, namely, that the large endothelial cells immediately surrounding the bacilli fuse to form a multinucleated mass, a giant cell, with the bacilli in the center. The increase in nuclei may then be accounted for by a division of the primary nuclei.

Granulation Tissue.—Giant cells are frequently seen in granulation tissue where they assist in the disposal of the necrotic tissue.

Tumors.—Giant cells are common to or may be found in all orders of tumors and are frequently seen in

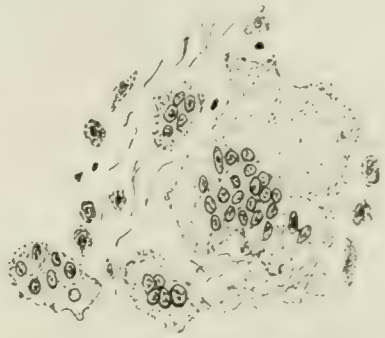

Fig. 2790.—Giant Cells in Granulation Tissue.

neoplasm undergoing degeneration. Von Hansemann classifies these giant cells as follows:

1. *Foreign body giant cells* found in necrotic and degenerating areas. These cells are like those in tuberculosis, having peripheral, or polar collections of nuclei and a central hyalin, or necrotic substance. They are endothelial or leucocytic in origin.

2. *Parenchymatous giant cells*, which represent modifications of the cells proper of the tumor, and due to nuclear and not protoplasmic division. The nuclei are variable in size, may be joined by fibrils, or bridges, or they may simply show lobulation. They

Fig. 2791.—Two Giant Cells from a Myeloid Sarcoma.

may be found in cancer and are especially common in endotheliomas. They are not constant, neither are they regularly distributed in such tumors.

3. *Myeloplaxes* differ from (1), in having the nuclei evenly distributed throughout the cell and, in that, the central area of the cell does not show disintegration. They differ from (2), in having nuclei of uniform size. These are found in bone-marrow as osteoclasts; in giant-celled myelomas of bone they are the characteristic cells, being present in great numbers.

Under pathological conditions they develop from the periosteum or marrow; some consider them as derived from the adventitial cells of the blood-vessels and they are intimately associated with the fine capillaries even in tumors. Ritter considers bone growth and bone absorption brought about by two states of the same cells. When the tumor arises in the marrow, it causes resorption of the bone.

The *sarcoblastic type of giant cell* has been seen in the red lake-trout. Here the tumor consisted of the

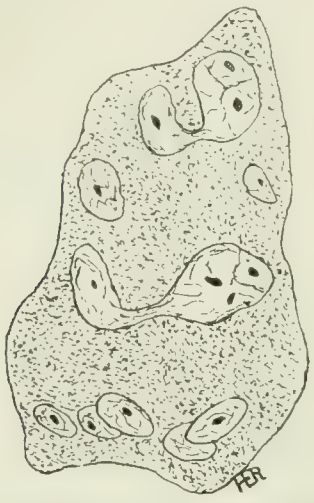

Fig. 2792.—Giant Cell in Experimentally Produced Glanders. (After Duval and White.)

sarcoblastic cells, the majority of which were multinucleated, some containing many scores of nuclei. The cells showed a tendency to elongation and, in parts, showed definite cross-striations.

Glanders.—Duval and White found giant cells in glanders and noted here that the giant cell nuclei resulted from amitotic division of the original nuclei.

H. E. Radasch.

Gibson, George Alexander.—Born at Kelliebank, Perthshire, Scotland, January 27, 1854. He received his academic education at the Universities of Glasgow

Fig. 2793.—George Alexander Gibson.

and Edinburgh, and was graduated M. D. from the latter institution in 1881. He held the following hospital appointments at one time or another during the course of his professional career: Resident Physician at the Royal Infirmary of Edinburgh; Assistant Physician at the General Hospital of Birmingham; Visiting Physician at the Royal Infirmary of Edinburgh; and Visiting Physician at the Deaconess Hospital. For a few years he was Tutor in Clinical Medicine in connection with the Extramural School at Edinburgh, and subsequently he held, for limited periods, the position of Lecturer on Materia Medica and that of Lecturer on the Principles and Practice of Medicine, in the same school. In 1897 he became one of the lecturers on clinical medicine at the Royal Infirmary. He died on January 18, 1913, from the effects of cardiac disease.

Of his published writings the following deserve to receive special mention: "A Treatise on Physical Diagnosis" (in conjunction with Dr. William Russell), third edition in 1902; "On Cheyne-Stokes Respiration," 1892; "On Diseases of the Heart and Aorta," 1898; "On Nervous Affections of the Heart," second edition in 1905; and in 1901 he edited a "Text-book of Medicine."

A. H. B.

Gibson, William.—Born in Baltimore, Maryland, March 14, 1788. He received his early medical education partly at the University of Pennsylvania and partly at the University of Edinburgh; he obtained the degree of Doctor of Medicine from the latter institution. From Edinburgh he went to London. He entered, as a private pupil, the family of Sir Charles Bell, who was at that time a practitioner of surgery in London. After an absence of three years Dr. Gibson returned home and entered upon the practice of his profession in Baltimore. Two years later (in 1812), he was appointed to the Chair of Surgery in the University of Maryland, but he held the position for only two or three years. After traveling a great deal abroad, in Asia and Africa as well as in Europe, he accepted in 1819 a call from the University of Pennsylvania to fill the Chair of Surgery, recently left vacant by the death of Dr. John Syng Dorsey. In 1855, thirty-six years later, he resigned this chair and was appointed Emeritus Professor of Surgery. His death occurred on March 2, 1868.

According to Stone, Dr. Gibson was very successful, both as a lecturer and as an operator. He was the first surgeon to perform the cesarean operation twice, successfully to both mother and child, on the same patient. (For details, see the *American Journal of the Medical Sciences*, August, 1835.) In 1824 he published his "Institutes and Practice of Surgery," a book which passed through six editions. The last ten years of his life were spent in Newport, Rhode Island.

A. H. B.

Gigantism.—The word giant is derived from the Middle English "geant," the equivalent of the French "géant," which may be traced back to the Greek γίγας.

Very early in the world's history we meet with references to huge beings of supernatural strength. Even before the flood, in the story of Noah, we are informed that "there were giants in the land in those days," and there are stray allusions to giants, Emmim and Anakim, in the accounts of the early Jewish conquests, in the sight of whom the people were "as grasshoppers," to use the characteristic Eastern hyperbole. Later, we have the celebrated battle between David and Goliath of Gath, one of the few remaining descendants of these Anakim, whose height was six cubits and a span. The Greeks, also, had their giants in the man-eating Cyclopes and Lestrygones. The Titans, too, forty-five in number, whose children were the Gigantes were of enormous size. They did not fear to encounter the gods, and were said to have heaped up mountains, to have "piled Ossa on Pelion," in order to scale the heavens. All nations, alike in their love of the marvellous and their sympathy with the weaker side, have their stories of unequal battles, recalling the

struggle between the pygmies and the giants, waged between brave men and monsters of immense size and strength, in which the lesser power comes off the conqueror. An instance that will be familiar to all is the popular nursery tale of "Jack the Giant-killer," which used to delight us so much in our youth. As is usually the case, human credulity and the innate tendency to exaggeration have magnified many of these tales beyond the bounds of credibility. While it must be admitted that in former times there have been individuals and even races that far exceeded in strength and stature the ordinary run of mankind, the application of the rigid canons of modern scientific inquiry has resulted in the dethronement of the supernatural element and the reduction of the subject, though marvellous enough still, to more manageable proportions. Before passing on to discuss the nature of this curious anomaly of development that we call gigantism, we may with advantage pause for a moment to determine what constitutes giant growth.

This is not so easy as it seems. If any one asks himself the question, "Where does giant growth begin?" he will at once realize that his ideas are somewhat hazy and his language conventional. In popular parlance a giant may be said to be any individual who exceeds in a notable degree the average height of human beings. A person of six feet six or upward would ordinarily be called gigantic. This is, of course, an exceedingly loose and by no means scientific definition. It fixes no limits, it takes no account of age, weight, or strength; in short, it lacks precision. Larcher defines a giant to be "A being who, free in other respects from all defect in the essential characteristics of the organization, excels notably in height other beings of the same race who have reached adult age." In such a case the structural harmony and the relationships between the different parts are manifestly normal, the sole deviation being the striking increase in size. It is scarcely necessary to point out that this definition portrays for us the ideal or perfect giant, a being more often read about than seen. No doubt there have been individuals of great size and strength, handsome, well proportioned, and well balanced in all their faculties, but these are the *rarœ* or rather the *rarissimæ aves*. As a matter of fact, the immense majority of giants present the unmistakable stigmata of defect or degeneration. The definition further ignores the fact that gigantism is a process, an anomalous one it is true, but still a process of growth which may and does manifest itself in embryonic life and childhood, as well as in the adult period. Pierre Marie recognized two forms of gigantism: (1) *True gigantism*, consisting in a simple exaggeration of the normal process of growth; and (2) *symptomatic gigantism*, a manifestation of pre-existent disease. Meige would restrict the term gigantism to Marie's second class on the ground that the members of the first group are in all respects normal persons, differing in no way, save in size, from other individuals of the same species. This, while no doubt contributing to precision of language and lessening the possibility of confusion in description, is in my opinion too extreme a position to take, for who will maintain that an exaggeration of a normal process of growth is not a pathological manifestation? We ought not, therefore, hastily to conclude that true gigantism and symptomatic gigantism are necessarily or essentially different processes, or that the former should be left out of our consideration of the general subject of gigantism. We shall be helped considerably toward a proper conception of what constitutes giant growth if we consider briefly what may be called the "law of deviation" enunciated by Thoma.

Thoma states, on the basis of an extended series of observations, that in adults the normal length of the body averages approximately 169 centimeters in the male and 163 centimeters in the female; the normal average body weight is 60 kilograms and 56 kilograms respectively. Considerable variations on one or other side of this norm occur. In one-half the total number of individuals the amount of deviation is anywhere from 0.0 to 3.8 centimeters for height, and from 0.0 to 5 kilograms for weight. In accordance with observations he has made, Thoma finds that the fifth multiple of the figures representing the amount of normal deviation, namely 19 centimeters and 25 kilograms, is exceeded only once in a thousand individuals. According to this an adult male would be regarded as a giant if his height exceeded 169 plus 19 or 188 centimeters, or if his weight were more than 60 plus 25 or 85 kilograms. The normal limits, however, for the upper well-nourished classes are somewhat higher than the figures given, namely, 175 centimeters and 66 kilograms, so that the lower limit for giant growth would be more correctly placed at 175 plus 19 or 194 centimeters, and 66 plus 25, or 91 kilograms (6 feet 4½ inches, and 200 pounds 5½ ounces). In the case of new-born infants the normal average for length is 50 centimeters and for weight 3.2 kilograms. The amount of deviation is approximately 1.4 centimeters and 0.28 kilogram respectively. Applying the same rule we may assume giant growth in children if they exceed 57 centimeters in length and 4.6 kilograms in weight. For Thoma, then, a giant is literally a man in a thousand. We cannot, however, assume that because an individual exceeds these dimensions he is necessarily a giant. It should be noted that height and weight are not necessarily closely correlated. In true gigantism no doubt they would be, but in many cases we find that those gigantic in stature are not heavier than many normal persons. This is often to be explained on the score of some wasting disease which is present, or that the individuals in question have died or been observed before the consolidation of the body had been properly attained. Further, an excess in weight above the limit of 91 kilograms cannot in itself constitute gigantism, for this weight is frequently attained by those who would be regarded as normal individuals, and has also been attained in cases of diffuse lipomatosis, elephantiasis, and when large tumors are present. Gigantism is quite different from this. Properly understood, it implies not a mere increase in the bulk of any tissue or group of tissues, but rather an abnormal increase in the size of the body as a whole, due to some peculiar and inherent nutritive disturbance. The term *macrogenesy* would perhaps most correctly designate the condition.

Gigantism manifests itself in an excessive growth of the bones, more especially in the direction of length, but also to some extent in thickness. The long bones are most noticeably involved, but all the bones of the body may be to some degree affected. With this there is a corresponding increase in size of the nerves, vessels, and soft tissues generally. The most striking and constant feature in giants, however, is their great height. The deviation in weight is less apparent, is usually less and rarely more than the increase in height would warrant.

From a pathological standpoint gigantism belongs to the group of tissue hypertrophies, of which there are many less extreme manifestations than the complete giant. Local hypertrophies of undoubtedly developmental origin are not infrequently met with, particularly in the head and extremities. In the case of the head the bones of the cranium and face are usually involved, giving rise to an extensive and remarkable deformity (leontiasis ossea of Virchow), the exact nature of which is somewhat obscure but appears to be essentially a diffuse hyperostosis. The form found in childhood is especially common in the upper limbs, and may be unilateral or bilateral. Apart from these instances of local gigantism, which are characterized mainly by an abnormal increase in the bulk of the affected part, there are other conditions, regarded by some as forms of gigantism, in

which the excess is numerical, as, for example, polydactylism, accessory ribs and vertebræ, and supernumerary organs.

Gigantism, or macrogenesy, is comparatively rare as a congenital anomaly. Fuchs in the extensive material of the Lying-in Hospital at Kiel found the average weight of the new-born child at full term to be from 3 to 3.5 kilograms, figures which agree accurately with those given by Thoma. This limit was not often passed, and a body weight of 5 kilograms (11 pounds) was of the greatest rarity. In 3,600 births at the Dublin Rotunda only one child reached 5 kilograms. Ahlfeld in fifteen years' experience met with no case above 5.1 kilograms. Spiegelberg and Wiener observed two infants weighing 5.2 and 6 kilograms respectively. Baudelocque in many years saw only one infant that reached 6.375 kilograms. Fuchs has described in detail two infants that weighed 6.1 and 7.55 kilograms and measured 60 and 65 centimeters respectively. The most extensive statistics are those of von Winckel, who in 30,000 births found no child reaching 6 kilograms; in 17,000 cases at Munich only 5 were found weighing from 5 to 5.32 kilograms. These dimensions, striking as they are, have been considerably surpassed by some found in English and American literature. Eddowes mentions the birth of a child weighing twenty-two pounds two ounces. The mother was thirty-three years of age, and had previously borne two children of large size. Chubb met with one case in which the child weighed twenty-one pounds. The other children of the family were exceptionally large. The fact that some women have a tendency to bear large children is also well illustrated by an observation of Dickinson's, where a woman was delivered by craniotomy and evisceration of a child weighing sixteen pounds. Her first child weighed nine pounds and her second twenty. Beach records the birth of the child of Captain Bates and Anna Swann, both of gigantic proportions, which weighed twenty-three pounds twelve ounces. Baldwin quotes the case of a woman who after having three miscarriages finally had a child weighing twenty-three pounds. There are at least ten other instances on record of new-born children weighing from thirteen to twenty pounds. The largest child I have been able to find recorded is a case of Dubois, which attained the almost incredible weight of 11.3 kilograms (24 pounds 13½ ounces).

As will readily be understood, the fate of giant children is often an untoward one. Not infrequently they die in the later months of gestation. When brought to term, they have to be delivered by operative interference of some kind, and are often still-born. It is an interesting fact that the dystocia is brought about, not by the head, which usually, unless hydrocephalic, does not exceed in size that of a normal child, but by the size of the trunk. The biacromial diameter is excessive. In Dubois' series of forty-four cases only twenty-six were born alive. Children of eight kilograms and over are invariably still-born. In those that survive, the excessive size at birth is sometimes compensated for by slow growth subsequently, but the pathological nature of the process is sufficiently indicated by the fact that such children often grow very fast and attain puberty in the third to the sixth year. It is perhaps questionable whether all cases of precocious development, wherein the individual attains the structural and functional characteristics of the adult in early childhood, are to be regarded as manifestations of gigantism. When associated with excessive height and weight no doubt they should be. Some at least have this in common with gigantism that they show evidences of early senility. Development is rapid and decay is premature. Phlegmon ("De Mirabilibus," cap. 32) is the authority for the statement that Craterus, the brother of King Antigonus, was an infant, a young man, married and begat children, and became an old man in the short space of seven years. In 1741 a boy was born at Willingham, near Cambridge, who when twelve months old presented all the appearances of puberty and died an old man at the age of five years (Philos. Trans. of the Royal Soc. of London). The subsequent history of unusually large children is unfortunately not often to be traced, but there is some slight evidence to show that they may develop into gigantic adults. Bonardi reports an interesting case which throws some light upon this point. A boy at the age of fifteen had the size and development of an adult male. At twenty-two he began to suffer from pains in the head with nausea, and soon after the hands, feet, maxillæ, and tongue began to increase in size. At the age of twenty-nine he measured 194 centimeters, and presented all the signs of acromegaly. In other instances, too, the abnormal increase in size has been known to begin quite early. Gilbert of the Hôpital Broussais met with an individual who began to grow rapidly after an attack of some acute fever in his earliest infancy and eventually attained the height of 196 centimeters. The American giant Wilkins began to grow rapidly at the age of four, and reached his full height (245 centimeters) at eighteen. As a rule, however, the excessive growth does not become in evidence until some time between the tenth and twentieth years, usually with the onset of puberty.

The student of ancient lore will be interested and amused to see how superstition and the love of the marvellous have combined to render many of the accounts of giants that have come down to us thoroughly unreliable. Judging from these stories, the height to which the human race may attain has varied between wide limits. Pliny, like Augustine, believed that the stature of mankind had deteriorated, but this is not substantiated by the examination of such ancient remains as we possess. The rabbinical legends teem with incredible accounts of the height of the various Biblical characters. Adam's height was calculated to be one hundred and twenty-three feet and Eve's one hundred and eighteen. According to the Biblical account the bedstead of Og, King of Bashan, was nine cubits long. Pliny mentions the giant Gabbaras, between nine and ten feet high, who was brought from Arabia by the Emperor Claudius, and states further that the remains of Posio and Secundilla, found in the Sallustian Gardens in the time of Augustus Cæsar, measured each ten feet three. Josephus refers to a Jew nearly eleven feet high, who was sent as a hostage to Rome by the King of Persia. Some remarkable stories are told of the Emperor Maximin (C. Julius Verus Maximinus) who was born in 173 in one of the frontier villages of Thrace. A shepherd in his youth, he soon became noted for his extraordinary height and strength. He took part in the games given by Septimus Severus to celebrate the occasion of the birth of his son, and overcame sixteen of the most powerful wrestlers without taking breath. The Emperor attached him to his own person and he was made a centurion by Caracalla. Capitolinus says that he was a finger's breadth over eight feet in height. His thumb was so large that he could use his wife's bracelet for a ring. He stopped a wagon with one hand, broke the jaw of a horse with a blow of his fist, and could break its leg with a kick. He is credited with eating forty pounds of meat in a day and used to drink as much as a Capitoline amphora (about twenty-six liters). He became tribune under Alexander Severus, and, conspiring against him later, was elected emperor. He reigned for three years, execrated for his cruelty, and was finally assassinated by the soldiers in 238.

Coming to more recent times, we have some equally extraordinary tales brought back by travellers. Magellan is said by some to have given the name Patagonia to the country he discovered because its inhabitants measured five cubits. Lemaire, in de-

scribing his voyage in 1615 to the Straits of Magellan, states that at Port Desire he found several graves covered with stones in which were skeletons of men measuring from ten to eleven feet. More recent travellers have, however, found the Patagonians to be not excessively large; in fact many of them are rather diminutive. The naturalist Turner believed that he saw on the River Plata near the coast of Brazil savages twelve feet high. Accounts more marvellous still are given of giants from nineteen to thirty-six feet high, who have existed at various times in Europe. These are based on the discovery of bones of prodigious size, which were erroneously regarded as human. In those days nothing was known about comparative anatomy, and the remains in question were no doubt those of some of the lower animals. Sir Hans Sloane, in an elaborate and learned disquisition on the subject, came to the conclusion that the bones referred to were parts of whales, mastodons, elephants, or other enormous beasts, although he thought that some of the stories could not be entirely discredited. It is a fact, however, that in more recent times, when such matters are much more narrowly scrutinized, no such instances of excessive height can be substantiated. Buffon, the great naturalist, usually a reliable authority, had no doubt that human beings had existed who were from ten to fifteen feet high. It is not until we come to the eighteenth century that we get reliable data as to the height of giants. According to Dana[1] not more than 100 giants have been exhibited in public since 1700, and of this number only about twenty were said to have been over eight feet. Topinard measured the tallest man in the Austrian army, and found him to be eight feet four and a half inches. Winckelmeyer was eight feet six inches. Marianne Wehde, a more recent German giantess, was eight feet four and a half inches when sixteen and a half years old. In view of these observations we must seriously question whether any human being has ever exceeded nine feet in height. Quite a number of giants have been recorded who measured between seven and eight feet, but above this limit the cases are extremely few. The history of these is often extremely interesting. Queen Elizabeth's porter, whose portrait, painted by Zucchero, is now in Hampton Court Palace, was seven feet six inches high. Walter Parson, the porter of James I., was as big. William Evans, the porter of Charles I., was about eight feet high. Cromwell's porter, Daniel, who died a lunatic, attained the height of seven feet six. In the reign of George I., an Englishman, seventeen years old and eight feet tall, was exhibited at the Bartholomew Fair at Smithfield. "Big Sam," the porter at Carleton Place when George IV. was Prince of Wales, was eight feet in height. In a Dutch village in 1712 there died a fisherman called Gerrit Bastiaansen, who measured eight feet and weighed 500 pounds. As a contrast to this we may cite a giant who was exhibited at St. Petersburg in 1829, who measured eight feet eight, but withal was thin and emaciated.

One of the most celebrated giants was Cornelius McGrath, whose skeleton is now in the museum of Trinity College, Dublin. He was born in 1736 in the county of Tipperary. His parents and the other members of the family were of ordinary size. After the age of fifteen he began to suffer from violent pains in the limbs and began to grow rapidly. At the age of sixteen he was six feet nine. In 1753, six months later, when he first exhibited in public he measured seven feet three inches in his stocking feet. It is said that he was ungraceful in appearance, of low intelligence, and spoke in a childish manner. He died at the early age of twenty-four. His skeleton measures seven feet eight inches.

John Middleton, called the "Child of Hale," was born in 1752 at Hale in Lancashire. His portrait is preserved in Brazenose College. He is said to have measured nine feet three inches.

O'Brien or Byrne, the "Irish Giant," is celebrated not only for his great height, but for his connection with the distinguished anatomist John Hunter. Hunter was particularly anxious to secure his body and made the most extraordinary exertions to obtain it. O'Brien was aware of this desire on the part of the anatomist and was correspondingly averse to being "set up" as a specimen. Shortly before his death, which occurred at the age of twenty-two, O'Brien bribed some of his friends to take his body, and after weighting it with lead to sink it in the sea. The undertaker, however, who had been previously interviewed by Hunter, managed to have the coffin locked up in a barn while the escort was refreshing at an inn. Thereupon some men, stationed there for the purpose, substituted an equal weight of paving stones for the body which was forwarded that night to Hunter. He took it in his carriage to Earl's Court, where it was immediately prepared. It is estimated that it cost nearly five hundred pounds to secure the body. O'Brien is said at the time of his death to have been eight feet four inches high. His skeleton, however, measures only seven feet seven. It is now, together with the kettle in which the body was boiled, in the museum of the Royal College of Surgeons in London.

The successor of O'Brien, Patrick Cotter, who for a time exhibited under his name, was born in 1761. At his death, which occurred at the age of forty-five, he is variously estimated to have been from eight feet one to eight feet seven in height. At one time he was examined by Dr. William Blair, who found him to measure about seven feet ten. He was badly proportioned, and looked like a weakly or even imbecile person. His forehead was low, his pulse feeble, his voice weak, and he suggested in appearance a sickly child that had grown too fast.

Robert Hale, the "Norfolk Giant," who died at Yarmouth in 1843 at the age of forty-three, was seven and a half feet high and weighed 452 pounds.

Among the better known of the exhibited giants were Captain Bates, of Kentucky, and his wife, Anna Swann, of Nova Scotia. Captain Bates enlisted in the Southern army at the beginning of the American Civil War, being readily accepted on account of his size, although he was only sixteen years of age. By the end of the war he had attained the height of seven feet two and a half inches. He gradually increased in weight also until he turned the scale at 450 pounds. While in England in 1871 he married at St. Martin's-in-the-Fields Miss Anna Swann, who measured seven feet five and a half inches. On neither side were the parents of more than ordinary stature.

Chang, a celebrated Chinese giant, died at Bournemouth in 1896, at the supposed age of fifty-one. He was upwards of eight feet high.

At the Alhambra in London in 1882 was exhibited the "Queen of the Amazons," who was eighteen years old, and measured eight feet and half an inch.

The giant Turner, studied by Cushing in 1910, was eight feet three inches (after death) and weighed 275 pounds.

We owe much of our present knowledge of the processes of growth and development to the epoch-making work of Winslow, Haller, Meckel, and the Saint-Hilaires, father and son. Although of late the interest of scientific men has been somewhat revived in the subject we cannot as yet be said to have attained finality, though we are beginning to apprehend more fully the nature of the problems involved. We are now realizing the fact that growth and development are a very complicated matter. We see, for instance, that we must draw a distinction between mere growth, or what may be called vegetative force, function, and reproductive power. These three factors are more or less correlated, but the correlation often varies both in kind and in degree. Certain cells are specialized for growth, others for function, others for prolifera-

tion. All cells may at some time in their life history be specialized in one or other of these directions according to the demands made upon them, but they cannot be specialized in all three directions to the same extent at the same time. Thus a cell that is about to divide ceases to grow and enters into a resting stage before mitosis occurs. And other illustrations might be given. Moreover, what is true of the cell is true of the community of cells known as the individual. Up to a certain period of life the forces of the body are concentrated toward the main object of growth. Later, function becomes more in evidence. Last of all the power of reproduction becomes established and perfected. In gigantism disturbance of growth in the direction of increased stature and weight is the predominant feature, but, as we shall see, this does not occur as a rule without exacting a corresponding penalty in the degradation of the general bodily functions and the power of reproduction. The causes which lead to this result may be inherent in the germ cells so that they make their influence felt quickly in the construction of the organism, or they may become operative subsequently to fertilization and segmentation of the ovum, either during intrauterine life or after birth. These influences may, further, be exerted upon the body as a whole or on some part of it. There is therefore a family relationship between gigantism, dwarfism, and the various malformations and monstrosities. In both dwarfism and gigantism, which are not, as might at first sight be supposed, perfect opposites one of the other, there is not merely an inhibition or an exaggeration of the normal processes of growth, but in the vast majority of cases something more, namely, a perversion of growth. In the normal infant at birth, the head and trunk, but particularly the head, are relatively large. As the time of puberty approaches the picture changes. Growth is rapid and irregular. The limbs are now disproportionately large, the hands and feet being especially prominent. To use a common expression the child has become the hobbledehoy. Only in the later period of puberty does the trunk enlarge, the figure consolidate, until the perfect proportions of the adult are attained. There is a striking parallel between the hobbledehoy stage and what we find in gigantism. In giants, growth is also disproportionate and irregular. The head is often small, or at least about the same size as the head of a normal youth or adult of the same age; the increase in height is mainly due to the excessive growth of the lower extremities as compared with rest of the body. Here, however, the parallel ceases. Giants are often weakly rather than strong; the sexual organs are apt to be badly developed, and the sexual proclivities are sluggish or delayed. They are liable to contract disease and show signs of premature senility; in fact they rarely reach middle life. Dwarfs, on the contrary, are long-lived. They frequently have the relatively large head of the infant, with evidences of delayed ossification of the cartilages, and genital inadequacy, facts which have caused many to regard dwarf growth as really infantilism. Unlike the giants they frequently possess average or more than average mental powers. It is clear that in both gigantism and dwarfism the disturbance, whatever it is, manifests itself mainly in the rate and extent of the growth, but still to a noteworthy degree in disordered function. And it is not merely the process of ossification that is at fault but the body as a whole—bones, soft parts, and internal organs—is involved. Nevertheless the disturbance of ossification appears to be the controlling force, for it undoubtedly dominates the picture.

Normally, the growth of bone depends on the activity of certain specialized cells—the osteoblasts—which are chiefly situated in the deeper layers of the periosteum, at the extremities of the bones, and along the interosseous sutures. Growth in thickness takes place from subperiosteal osteoplasia; growth in length is due to the influence of the osteoblasts in the spongy ends of the bones and in the epiphyseal cartilages. Inhibition or exaggeration of stature is due in the main to dystrophic changes at the extremities of the long bones, although subperiosteal osteogenesis is also to some extent interfered with. The results depend not only on the inherent vegetative forces at work in the cells, but on the condition of the epiphyseal discs. So long as the discs are movable, growth in length of the bone is possible. This is interestingly borne out by recent investigations with the *x*-rays in certain forms of anomalous growth.

In acromegaly, where the increase of size of the bones, notably at the distal ends, is in breadth and thickness, rather than in length, there is complete union or synostosis of the epiphyses. With regard to giants we unfortunately have no extended information on this point, but I think we may fairly infer that, while growth is in excess, epiphyseal synostosis is absent or delayed. Cushing has studied a giant (Turner), who was thirty-six years of age. He presented little or no sign of acromegaly, and the epiphyseal line at the lower end of his radius was distinctly visible on the skiagram. Cases are also recorded where giant growth has suddenly supervened in quite young children, in whom it is almost a certainty that the epiphyses were ununited. Contrariwise, cases are reported of acromegaly in young persons, a girl of nineteen (Claude) and a girl of fourteen (Franchini and Giglioli), in whom union of the epiphyses was demonstrated. Joachimsthal found in some lilliputians that he examined that the bone formation was delayed, and the condition of the discs and of the bone generally was strictly comparable to that found in the child, although the subjects were in the neighborhood of thirty years of age. Hofmeister also in cretinism found that the epiphyseal discs persisted for a long time, and that the epiphyseal ends of the bones grew slowly. In chondrodystrophia fœtalis an ingrowth of periosteum has in some cases been observed between the disc and the end of the bone. The significance of this is not quite clear. The importance of the condition of the epiphyseal discs in modifying the extent and the direction of the growth is also prettily illustrated by the observation of Lorain, who found in some cases of dwarfism premature ossification and union of the epiphyses.

In our discussion of growth and its anomalies so far we have contented ourselves mainly with freeing the subject from entanglements, and so to speak preparing the ground for action. When we come to consider the more remote factors concerned in the question of growth we find ourselves in a much more difficult position. As we do not know what life is we can apprehend its methods and its manifestations only in an imperfect way. Many of our ideas, therefore, have to be based upon inference rather than direct proof.

The part played by heredity in gigantism, as in other anomalies of development, is of considerable interest and importance. This factor might be expected to be more prominent in cases of congenital gigantism, and as a matter of fact it is so, but its influence cannot be overlooked in the other forms. It is a matter of common observation that parents transmit their tendencies and peculiarities to their offspring, and moreover these peculiarities may be traced through several generations; in fact they may become familial or racial characteristics. This law manifests itself in many ways, in the size and configuration of the body, in the color of the skin, the mentality, habits, the susceptibility to disease, and in many minor traits. The peculiarities derived from the paternal and maternal sides may be of such a nature as to neutralize one another, or again they may unite their forces to produce an exaggerated effect, an effect so pronounced as to be marked at once as an anomaly. With regard more particularly to gigantism, we do not meet with the anomaly as a racial characteristic at the present

day. At most we can say that some races tend to be tall and large, while others are small or even dwarfed. If the ancient accounts are to be believed giant peoples have, however, existed. Whatever stress we may lay upon this, at the present time gigantism is a sporadic affection. It is a suggestive and striking fact that once the tendency toward gigantism is acquired it is apt to crop out at various times in the same lineal descent, exemplifying the law of atavism. Again it may often be noted that more than one of the children of the same household will be affected. A number of cases might be quoted to illustrate these points. In Dickinson's case mentioned above, a woman bore three children who weighed nine, twenty, and sixteen pounds respectively. Fuchs' case was a IX-para. Her sixth child weighed 6 kilograms, her eight 6.1, and her ninth 7.55. Her other children had also been heavy. The same thing has been noted by other observers. Goulart refers to a Polish giant who was exhibited in Paris in 1571, and was so tall that in a lofty room he could touch the ceiling with his head. He was married and had a son who promised to be as tall as he was.

James Toller, exhibited in London in 1815, was seven feet nine inches high. His parents were of normal build, but he had two sisters of gigantic stature. Louis Frenz, a French giant, who was born in 1800, and measured seven feet six, had two sisters as tall as he was and one brother who was much larger. The family history of Robert Hales, "the Norfolk giant," is also quite striking. His father was six feet and a half, his mother six feet, in height. One of his ancestors, who lived in the reign of Henry VIII., measured eight feet eight inches. Hales had five sisters who averaged six feet three and four brothers who averaged six feet six. The tallest of the sisters died at the age of twenty, measuring seven feet two. Captain and Mrs. Bates, both over seven feet, had a child which is almost the largest on record. One of the sisters of Chang, the Chinese giant, was even taller than he was, measuring eight feet four.

These facts suggest that this anomaly of growth is due to peculiarities inherent in the germinal cells of the parents. This view is supported by the observations of Engel-Reimers, who has emphasized the fact that excessive muscular development, the so-called "athletic habitus," appears to be due to an abnormal hereditary predisposition and not to hypertrophy from functional overactivity. This is well borne out by the physical condition in new-born giant children. They frequently present the athletic habit. The head is about the size of that of the normal infant, but the trunk is massive. Now this hypertrophy, if we can call it such, is clearly not due to mechanical work nor to compensation, nor to the other ordinary causes of overgrowth. It must be due to some disturbance of nutrition. The relative importance to be attached to peculiarities of the male and female germ cells is still in doubt, for in the recorded cases we rarely have any statement as to the physical condition and development of the father. From the instances cited it is evident that both germinal elements may play a part. But it is equally evident that some idiosyncrasy in the maternal organism alone is sufficient to produce the result. In Fuchs' case, for instance, the father is noted as having been in a poor state of nutrition. This has led Werth to suggest that the tendency to produce large children is due to an inherent peculiarity of the ovum, possibly to its large size. However this may be, we have sufficient evidence to show that large size on the part of one or both parents is not necessary to produce the result in question. Yet it seems probable that physical superiority in the mother, if not in height, at least in physical constitution and nutrition, is an important etiological factor. In 178 cases of large and giant children collated by Fuchs, 166 mothers are noted as being of more than usually strong physical development and nutrition. The remaining 12 were weakly, but in no case did their children exceed 4.36 kilograms in weight, a size which, according to our adopted standard, cannot be regarded as gigantic. In view of this fact we see that the influence of maternal development and nutrition assumes considerable importance. Exceptions to this, however, occur. In a case cited by Dubois, a woman with extensive tuberculosis gave birth to a child weighing 6.336 kilograms, and another with severe diabetes had a child of thirteen and a half pounds. Two possibilities must evidently be considered in this connection, a primary peculiarity of the ovum or sperm cell, or both, and a condition of increased intrauterine nutrition. The influence of peculiarities of the primitive germinal cells would perhaps be best illustrated by instances of the atavistic manifestation of gigantism, or in those cases, like that of Dubois, in which the maternal organism was conspicuously weak, for in the latter case increased intrauterine nutrition could obviously play no part. Some of the forms of minor terata, such as polydactylism, are no doubt also of this nature. Polydactylism has been known to run through a family for three four, or even five generations, being eradicated only in process of time by marriage with normal persons. Curiously enough polydactylism has been found associated both with dwarfism and with gigantism.

Intrauterine nutrition is undoubtedly a factor of considerable importance. In the article on *Nanism* or *Nanosomia* in this work the rôle played by intrauterine malnutrition in the causation of inhibited growth is dealt with at some length. Here syphilis, alcoholism, and tuberculosis, together with lesions resulting in interference with the free circulation of blood through the placenta, are of importance. Conversely, an overplus of nutritive energy might be expected to produce its effect upon the fruit. In this connection we have to take into account the condition and surroundings of the mother during pregnancy. Pinard compared the average weight of 500 new-born children whose mothers had worked up to the time of delivery with that of the same number of children whose mothers had rested during the later weeks of pregnancy. He found a notable superiority in weight and nourishment in the offspring of the latter class. In a similar inquiry Bachimontin a series of 4,445 observations found the excess in weight for the latter class of children to be, on the average, 300 grams. In this particular it should be remarked that very large children lead perforce to a condition of complete inactivity and inertia on the part of the women pregnant with them. This of course means rest which tends to increase in turn the size of the child. Thus a vicious circle is induced. The importance of intrauterine nutrition in modifying the weight of the fruit is well illustrated by the good effect of dieting in those cases in which a woman has either a tendency to produce large children or else has some contraction of the pelvis. By this procedure it has been found possible to deliver such a mother of a living child.

It has been thought by some that mothers in whom the function of menstruation was established early were more likely to have larger children than others, apparently on the theory that such persons were possessed of greater reproductive energy. Negri on the basis of 333 observations has stated that the children of mothers who began to menstruate early were both larger and heavier than the offspring of those whose menstruation was late in coming on. This has not been confirmed, however, by other observers. The point can probably not be decided until more studies on the subject are forthcoming. It is, nevertheless, true, so far as the records go, that large children are more likely to be borne by those who are at the height of reproductive activity and who have had previous children. In elucidation of this point we may perhaps quote Fuchs' statistics. In 176 of his cases, already referred to, the age was ascertained. These were divided as follows: I.

Under twenty years, 5; of this number 5 were primiparæ. II. Twenty to twenty-five years, 72; of this number 18 were primiparæ. III. Twenty-six to thirty-five years, 75; of this number 2 were primiparæ. IV. Thirty-six to forty-eight years, 24; of this number none were primiparæ.

Between the ages of twenty and thirty-five, the years of the greatest sexual activity, the number of large children was greatest. Now, taking the third class, we find that only 2.6 per cent. were primiparæ. If these results be compared with those obtained from a series of 1,000 normal births, in 342 of which the mothers belonged to the third age period, it will be found that there were 57 primiparæ, a proportion of 16.9 per cent. This corroborates the observation made a little while ago that certain women show a tendency to produce large children, or in other words that the tendency once manifested tends to perpetuate itself.

Some attention had been directed to the subject of prolonged gestation and its effect in producing large children. The statistics seem to show that this factor has a certain amount of importance, but it is probably effective only when combined with other causes. It does not seem to me, however, that it is justifiable to place cases of this kind in the same category with giant growth. If, for example, a child is retained within the uterus for 308 days instead of 280, it is practically in the same position as an infant one month old, due allowance being made for differences between intrauterine and extrauterine modes of nourishment. Such a child would derive no permanent advantage from its prolonged retention within the uterus, and would probably develop later much as other children do. In other words, the vitium of excessive growth is not inherent. Unfortunately many of these points we have touched upon cannot be verified by any large series of observations. Gigantism in the first place is much rarer than dwarfism. Then the majority of giant children are still-born. Even those cases in which giant growth manifests itself later in life are beset with difficulties. The number of carefully made studies is not great and prolonged observation is rarely possible, not only from the fact that giants are apt to die early, but on account of their nomadic kind of life.

In dealing with the question of heredity we have adduced numerous facts to show its importance in the causation of anomalous forms of growth. The influence of this factor, while perhaps more direct and striking in the case of giant births, is nevertheless, as we have shown, to be taken into account in the postnatal forms.

But besides this we have to consider the bearing of internal metabolism on the subject. The more recent work done on cretinism and the results of the experimental removal of the thyroid gland have taught us that a condition of athyroidea, which undoubtedly acts by perverting the metabolic processes of the organism involved, has a profound effect on the function of growth and development, namely, in the direction of inhibition. In that other most remarkable perversion of growth, acromegaly, where there are enlargement and deformity of the body, or excessive growth, gross lesions of the pituitary body have been found. Disorders of internal secretion obviously are of great importance.

The general resemblance between acromegaly and gigantism has led to the promulgation of the view that the two conditions are one and the same thing, and the controversy over this point has waxed hot and heavy. Without being prejudiced on either side, I think that the careful observer cannot fail to be impressed with the parallelism which exists between the two affections. Brissaud and Meige have been the chief exponents of the identity theory, while Marie, who first differentiated acromegaly as a disease entity, though he has somewhat receded from his first position that acromegaly and gigantism are entirely distinct, has not been entirely convinced by the arguments adduced against his position.

Marie in his first studies on acromegaly summarized it as a peculiar affection, characterized by a massive hypertrophy of the bones of the extremities and the extremities of the bones. He admitted that a number of cases had been confounded with gigantism, for the reason that attention had been directed to the excessive height to the exclusion of the less obtrusive signs, while the disease in those of normal stature had been overlooked. Shortly after, Guinon, following Marie's lead, took the same position that the two affections were essentially different, on the ground that as our knowledge had increased it had to be recognized that persons with acromegaly were by no means always gigantic; in fact they were often below the average height, and again that the configuration of the body was different in both. The various parts of the face and limbs preserved their normal proportions in gigantism while the course of the two affections was different. Guinon even went so far as to state that gigantism is as a rule simply an exaggeration of a normal process, while acromegaly is a disease. It is undoubtedly a fact that typical, or what we might call "text-book" cases of the two affections present an entirely different picture. There have been some giants that presented none of the morphological characteristics of acromegaly, as there have been persons with acromegaly that were not giants. It ought to be unnecessary, however, to point out that even the best-known diseases present at times wide variations from the type. The case of typhoid fever, for instance, need only be mentioned. This being the case it by no means follows that two diseases, at first sight dissimilar, have nothing in common, or even that they are not due to the same cause. The point may be further illustrated by the history of cretinism and myxedema. At one time it was believed that these conditions, which in many ways are so unlike one another, at least to superficial examination, were distinct diseases. More careful study has, however, shown that both depend on a condition of athyroidea, and few will be found now to deny that cretinism and myxedema are one and the same thing. The modifying factor has been found to be the age and the concomitant stage of development of the affected individual. If athyroidea becomes manifest in infancy before the bony skeleton is consolidated we get cretinism. If it develop later, when the bony skeleton is complete, the soft parts only are involved and we get myxedema. It is unsafe then to conclude that one and the same cause may not at times produce widely different results. In other words, the trophogenic function of the individual may be so predominant that it is sufficient to alter a morbid state almost beyond recognition. It has already been pointed out that the normal process of growth manifests itself most strongly at the epiphyseal ends of the long bones, and that increase in length of the bones is possible only so long as the epiphyseal discs remain ununited, save by the softer structures, to the diaphyses. Similarly, the abnormal processes of growth, such as dwarfism and gigantism, manifest themselves at the same points. Deficient vegetative energy in early life will result in stunting the growth of the long bones, and the same thing will happen if the epiphyseal cartilages are prematurely ossified. Excessive vegetative power during adolescence results in increase in height; if synostosis of the epiphyses has taken place, as is the case in adult life, then it is conceivable that increase in length being impossible, increase in breadth and thickness must occur. Do, then, acromegaly and gigantism bear to one another a relationship similar to that existing between myxedema and cretinism? Many facts point in this direction. Numerous observations have shown that acromegaly frequently supervenes on gigantism.

Surmont in 1890 reported a case of acromegaly in a girl of eighteen, in whom the symptoms were preceded by a notable increase in the size of the body. The enlargement was generalized, but most marked at the extremities. Byrom Bramwell mentions the case of a giantess who was attacked by acromegaly. Swanzy also demonstrated the lesions of acromegaly on the skeleton of McGrath, the Irish giant, before the Royal Academy of Medicine of Ireland. Shattock believed the skull of O'Brien to be acromegalic. In 1893 Dana published two case of acromegaly associated with gigantism, and he remarks that the coincidence of the two affections is more common than has usually been supposed. He further mentions a great many symptoms which they have in common, and brings out the most important point, viz., that out of twelve autopsies on giants the pituitary body was enlarged in ten. In the case of "Adma," a French giantess, who died at the age of twenty-one, measuring six feet eight and a half inches, Hutchinson states that the face and extremities presented the well-known features of acromegaly. At the autopsy the pituitary gland was found to be considerably enlarged. A striking case, also, is reported by Brissaud and Meige. J. P. Mazas, the giant of Montastruc, began to grow rapidly when thirteen years of age, and became very strong and robust. At twenty-one years he was 212 centimeters high, eventually reaching 220 centimeters. At the age of thirty-seven he experienced a severe pain in the back, which he attributed to lifting a heavy weight. Deformity of the back set in and his height began to diminish. He gradually developed enlargement of the face and extremities, headache, weakness, intellectual and sexual torpor, and all the classic symptoms of acromegaly. Sternberg, also, in an elaborate paper on the subject found signs of acromegaly in forty-two per cent. of giants. More recently Walker reported an instance of acromegaly in a boy, who began to grow rapidly when six years old, and who at sixteen was six feet five and a third inches high, and weighed 245 pounds. Bonardi refers to the case, already mentioned in another connection, of a boy who at the age of fifteen had the size and development of an adult male. When twenty-two years old he began to suffer from pains in the head and nausea. Soon after, general weakness set in, with enlargement of the hands, feet, maxillæ, and tongue. At twenty-nine he was 194 centimeters high and was typically acromegalic. By a careful study of the recorded cases we see, therefore, that a considerable degree of parallelism exists between the two affections. Perhaps the most important points are to be noted in the skeleton.

The typical features in acromegaly are enlargement of the bones of the face and extremities. The hands are "spade-like," and the fingers rounded. In severer cases all the bones of the body become involved. The thorax enlarges and the trunk becomes scoliotic, so that a loss of height takes place. There exist, however, lesser disturbances of bone formation that are difficult to class, being on the border line between gigantism and acromegaly. In such cases the dystrpohic disturbance is confined to one or more parts of a member, or to two members symmetrically. Such malformations may be both congenital and acquired. Of such a nature are those cases in which there is deformity of the face without enlargement of the hands. Chauffard reports a case in which a man of thirty-two presented the features of prognathism, macroglossia, prominence of the external occipital protuberance, headache, anemia, loss of vision to the right, and slight kyphosis. Some of the anomalies, then, that are to be found in acromegaly may be found without the other features of the disease in certain forms of developmental dystrophy, and may arouse a suspicion as to the acromegalic nature of the case. When such peculiarities are met with in giants we may properly inquire whether they are the stigmata of acromegaly, or whether they merely simulate that disease. In giants thickenings of the extremities of the long bones, hyperostoses, and exostoses have been noted, identical with those that for so long have been regarded as characteristic of acromegaly. Deformities of the knees, which as Osborne, Middleton, Schultze, Hitschmann, and Roswell Park have shown, are fairly common in acromegaly, have also been met with in gigantism. Lucas Championnière in 1899 demonstrated to the Academy of Medicine a giant, aged twenty-seven, who measured 203 centimeters, and presented an extreme genu valgum. This peculiarity has a double interest in that it affords a link between acromegaly and gigantism, and also connects the latter with infantilism. The curvature of the spine and the rounded thorax, so often found in acromegaly, have been found in gigantism, but our information is defective in this regard.

With respect to muscular power great variations may occur both in gigantism and in acromegaly. Several observers, notably Meige, Dallemagne, Virchow, P. Marie, Souza-Leite, Bourneville, and Regnault, have noted acromegaly developing in persons of exceptional muscular vigor. Some giants, like the Emperor Maximin and the Countess Lodoïska, have been of great strength. This, however, seems to be the exception. Geoffroy Saint-Hilaire states that giants are "without activity, without energy, slow in their movements, avoiding work, quickly fatigued; in a word, feeble in body as well as in mind." A myasthenia and general weakness are by no means uncommon in acromegaly.

As is well recognized there is a characteristic facies in acromegaly. Meige is our authority for the statement that giants who are still in the period of growth present no special facial peculiarities. In those who have ceased to grow there is an exaggerated development of the face as compared with the cranium. We can sometimes note that the malar eminences are prominent, the lower jaw enlarged, and the angle widened, while the lips are thick. The beard is often thin, the skin thick and dark, the pupils dull, and the whole appearance lacks vivacity. These peculiarities are by no means invariable in giants, nor indeed are they so in acromegaly. We have to allow here as elsewhere for individual variations. In fact, we may perhaps with Hoffmann distinguish between acromegaly of the soft parts and acromegaly of the bones. Meige is, on the whole, inclined to believe that the face in giants at one time approaches the acromegalic type, at another the infantile.

Vascular disturbances have been found in both acromegaly and gigantism. In both the pulse is slow, the circulation sluggish, and there may be varices.

Pains in the head have been found in both affections. Pains also in the limbs, vertebral column, and the viscera have been met with in about half the recorded cases of acromegaly. These may simply amount to a sense of fatigue or lameness, but may be actually articular, muscular or neuralgic. It is a popular belief that rapid growth in children is associated with "growing pains," and it is interesting that the same thing has often been noted in giants. In the case of McGrath, for instance, the increase in growth was associated with the most violent pains in the limbs.

Visual disorders have been met with both in acromegaly and in gigantism. In acromegaly, at least, they have been found to be dependent on the presence of a tumor of the pituitary body.

Polydipsia, polyphagia, and abundant sweating have been observed in both affections. Polyuria and glycosuria are occasionally met with in acromegaly and in giants who become acromegalic.

In both gigantism and acromegaly there is often to be noted sexual frigidity in the male, and amenorrhea in the female.

To sum up, the two affections frequently have the

following symptoms in common; asthenia in the widest sense of the term; muscular weakness, notwithstanding the absence of atrophy; intellectual degradation; melancholy; headache; diminution of sexual desire in the male; amenorrhea in the female; alterations in the skin varices. Lastly, of a great importance, lesions of the pituitary gland have been found in a majority of both affections.

Further, the influence of heredity is marked in acromegaly as in gigantism, and indeed it is not uncommon in probing into the family history to find that acromegaly and gigantism are liable to be met with in the same family. Schwoner, for instance, records a case of acromegaly in a woman of forty-five, whose mother had become acromegalic at fifty. All the members of the family on both sides of the house are noted as having been of great stature. Lackey describes a case of acromegaly in a negro who reached the extraordinary height of eight feet six. His grandfather is said to have been a giant. Possibly here we have to deal with an inherited functional instability of the pituitary gland, for it is this organ which, as we shall see, is the dominant factor in the production of skeletal overgrowth.

In view of the facts outlined above, Brissaud and Meige would discover a general principle underlying the dystrophic disturbances that result in excess. Growth at all periods of life tends to be manifested most conspicuously at the epiphyseal ends of the long bones. The effect produced is controlled by the age of the patient, or, in other words, by his vegetative capacity and the condition of his epiphyseal cartilages. The same pathological process which in the young gives rise to gigantism will, if continued after the normal period of growth in stature is passed, cause acromegaly. If it becomes operative in later youth, when the bones are largely formed but growth is not complete, we get a combination of acromegaly with gigantism. This is to some extent corroborated by the lesions in acromegaly, for, as Marie himself has shown, in cases of acromegaly that begin early in life, the extremities are more elongated than thickened, and are quite unlike the spade-like extremities characteristic of the disease as it occurs in later life. Further, it may be safely stated that acromegaly has never preceded gigantism, while acromegaly has succeeded gigantism in almost half the cases. Brissaud and Meige, however, would go further. They see the same principle at work in the chronic rheumatism so-called of the aged, in rheumatoid arthritis and gout; in youth, in gigantism; in adult life, in acromegaly; in old age, in nodes. They support this by an observation made by Gaston and Brouardel with the x-rays on a woman of sixty, who began to show signs of acromegaly at forty-two after the menopause. The disease was slowly progressive, and thickenings in the form of nodules could be made out on the epiphyseal lines.

While not endorsing unreservedly the rather striking proposition put forth by Brissaud and Meige, that "acromegaly is gigantism of the adult; gigantism is acromegaly of adolescence," it seems to me that the unprejudiced observer cannot fairly deny that they have proved their main contention. There is undoubtedly a close connection between acromegaly and gigantism, and the two affections in a large proportion of cases merge gradually one into the other. Gigantism frequently becomes acromegaly. But how about the other fifty-eight per cent. of cases of gigantism that present no signs of acromegaly? Are these, too, of the same nature, or are they in a different category? It is not impossible nor even unlikely that some of them are due to the same factors as acromegaly, as it is ordinarily understood. Here we have to consider the natural variations of disease. Diseases do not invariably run their course. They may become ameliorated or may be aborted. Acromegaly itself may present an extremely slow progression, and in fact may cease to advance. A fatal termination does not always occur. It may well be, therefore, that acromegaly beginning in early adolescence may progress only sufficiently far to produce increase in length of bone without the other signs supervening. It may be recalled in this connection that the majority of giants die early. Byrne, the Irish giant, died at twenty-two; James Toller at twenty-four; the "Queen of the Amazons" at about twenty. This may perhaps be the effect of the acuteness of their malady, but in many cases it is due to intercurrent disease, as the resisting power of giants is notoriously low. However this may be, it is plain that many giants die before the period of age incidence of acromegaly, that is to say, before adolescence is completed. We cannot therefore say that they would not have become acromegalic had they lived. It is possible, therefore, that a majority of the cases of gigantism are to be explained on the same pathogenetic principles as acromegaly.

There has been considerable debate as to the exact nature of the cause or causes at work in acromegaly. Klebs advanced the theory that acromegaly is due to angiomatosis. Vascular lesions are undoubtedly present both in acromegaly and in gigantism. Witness the arteriosclerosis, the varices, the vasomotor ataxia, and the hypertrophy of vessels to adjust themselves to the increased size of the body. But there is no proof of any new formation of vessels. Lancereaux, again, has suggested that it is a trophoneurosis. The enlargement of the hands and the disturbed innervation met with in syringomyelia might suggest this. This view is not, however, supported by any known facts. von Strümpell has thought that it is a congenital dystrophy. The majority of observers are, I think, practically agreed that acromegaly, like gigantism, is dependent on some gross lesion of the pituitary body, in the form of hypertrophy, cystic growth, adenoma, or other tumor growth. Osborne believes that gigantism in its perfect development is due to a normal hypertrophy of the pituitary gland; that is, to a hypersecretion occurring at the age of puberty or age of general or symmetrical body growth and development. He believes further that gigantism will remain such as long as the pituitary body is in normal hypertrophy, but that these cases of gigantism will assume later an acromegalic type, if, as is often the case, the pituitary body begins to take on pathological conditions. In other words, he believes that an excess of normal secretion from the pituitary gland is the cause of gigantism, while perverted secretion is the cause of acromegaly. This conception is very different from that of Brissaud and Meige, in that it attributes the lesions, which we call gigantism and acromegaly, to two distinct and separate states of the pituitary function. Brissaud and Meige's view implies that the same condition of the pituitary function is at work in both cases, any differences in the results produced being attributable to the age period at which the process begins. For my part, I do not like the term "normal hypertrophy," as applied to the pituitary. We have, it is true, what might be called normal, or physiological, hypertrophy in the case of the pregnant uterus and possibly in the functioning breast, yet this is but a temporary condition and is paralled, so far as I know, nowhere else in the body. Gigantism is an abnormal condition, and to my mind cannot be explained on the basis of a "normal" hypertrophy. It may, however, be true that it is due to an excess of pituitary secretion. But if this can produce increase in the length of bone, why is it not also competent to produce increase in thickness of bone? One seems as likely as the other. Whether acromegaly is due to a hypersecretion on the part of the pituitary, as many seem to think, cannot, however, be regarded as settled.

The later work, experimental and operative, notably the remarkable studies of Harvey Cushing, have done much to clarify our ideas on this interesting subject

It is now known, for example, that the hypophysis is a gland possessing a dual character, the function of the anterior portion being distinctly different in many ways from that of the posterior. It is the secretion of the pars anterior which has most to do with skeletal overgrowth. While it is not yet admitted on all hands that the peculiar skeletal changes characteristic of gigantism and acromegaly are due to hyperplasia of the pars anterior, with the production of an excessive or perverted secretion, all the available evidence at our present command points strongly in that direction. One thing at least seems to be now universally accepted, that is that gigantism and acromegaly are manifestations of one and the same morbid process. The condition of the epiphyseal discs controls the pathological situation. The dictum of Brissaud and Meige, above quoted, may now be changed, with Launois and Roy, into "Le gigantisme est l'acromégalie des sujets aux cartilages épiphysiaires non ossifiés, quel-que soit leur âge."

The evidence in favor of the hyperpituitarism concept of acromegaly may be summarized as follows:

(1) In gigantism, acromegaly, and eunuchism, there can usually be demonstrated an enlargement of the pituitary gland or an actual cellular hyperplasia.

(2) Extirpation of the pituitary body leads to stunting of the skeletal growth in experimental animals, and an analogous state of affairs has been found in human beings the subject of tumors, injuries, and other destructive processes affecting this organ.

(3) Acromegaly, as Cushing has shown, tends to assume the pathological picture characteristic of pituitary glandular insufficiency, adiposity and high sugar tolerance. The fact that there is a low assimilation limit for carbohydrates in the earlier stages of this disease argues for a coincident period of functional overactivity.

(4) Partial removal of the pars anterior in certain cases of acromegaly has led to apparent improvement in the symptoms. Conversely, hypophyseal feeding has caused an aggravation of them.

Tumors, cysts, and plain hypertrophy of the pituitary have been found in the majority of autopsies on acromegalic cases, and tumors of the pituitary in acromegalic giants (Buday u. Jancto, Oestreich u. Slawyk). Possibly simple hypertrophy or adenomatous growths may imply oversecretion: but cysts or destructive tumors, like the sarcomata that are so frequently found, might be interpreted as lessening the amount of secretion. Yet it should be pointed out that malignant tumors and cysts, or other degenerative conditions, may be "end" stages of a previously existing hypertrophy and need not therefore be interpreted as upsetting the validity of a theory based on oversecretion. Conversely, tumors of the pituitary may exist without signs of acromegaly, as in two cases that have come under my own observation. Both were malignant (one sarcoma and one endothelioma). Here, on a superficial consideration, one would assume either that the pituitary, despite its transformation, was still able to furnish the proper amount and kind of secretion, or else that compensation had taken place. We are realizing more and more the importance of the principle of compensation in regard to the body metabolism. We see, for instance, that there is a close relationship between the thyroid gland and the pituitary body. In acromegaly the thyroid gland has been found hypertrophied, cystic, or atrophic, and the disease may be complicated by the symptoms of exophthalmic goiter or myxedema. In this connection may be mentioned a most remarkable case, reported by Pope and Clarke, in which a man suffering from acromegaly had a daughter with myxedema and an atrophied thyroid, who at the age of twenty presented the physical and mental characters of a child of five. Ponfick, Hymanson, Pineles, and Green, in particular, have noted the association of acromegaly with myxedema, and Murray its combination with exophthalmic goiter. Conversely, the pituitary has been found enlarged in cases in which the thyroid was atrophied (Boyce and Beadles), and when this occurs it seems to prevent at least the immediate results of thyroid defect, namely, cretinism or myxedema. In the article on *Nanism*, by the present writer, elsewhere in this work, the relationship of thyroid dystrophy to that other anomaly of growth allied to gigantism, namely, dwarfism, is dealt with at length, and it is there shown how the condition of athyroidea may result in inhibited growth and genital insufficiency. The stigmata of infantilism in acromegaly and in gigantism have suggested the possibility of disorder of the thyroid in these affections, and there have not been wanting those who would attribute acromegaly to thyroid dystrophy. Facts, however, do not favor this view. A third possibility, however, is suggested by the observations of Erdheim, Goetsch and Dandy, namely, that the necessary secretions may be supplied by cells, of the nature of "rests," derived from the epithelium of the ectodermic diverticulum of Rathke, situated in the hypophyseal cleft or along the line of the craniopharyngeal canal, or by the dural parahypophysis.

Genital hypoplasia and malformation, as well as genital inadequacy, have been met with in dwarfism, cretinism, infantilism, gigantism, and acromegaly, and this leads us to discuss in how far disorders of the sexual apparatus are responsible for anomalies of growth. In this connection a number of interesting facts may be adduced. The sexual languor, as it might be termed, found in both acromegaly, and gigantism, has been referred to. Garnier and Santenoise have observed a case of gigantism associated with feminism, cryptorchidism, and polysarcia. Thoma mentions having met with defective formation of the genital organs in a case of hemihypertrophy. In acromegaly, as soon as the changes in the bones become manifest, the secondary sexual attributes are changed. In the male the hair becomes scanty, while in the female hair is apt to grow on the face much as it does after the menopause or in ovarian disorders. The larynx hypertrophies and the voice deepens. Infantilism and hypoplasia of the genital organs have also been observed in cases of tumor growth in the pituitary in the absence of signs of acromegaly. Some years ago I performed an autopsy on a woman about thirty years of age who had a perithelial sarcoma of the pituitary without signs of acromegaly. She had menstruated only once and the genital organs were markedly undeveloped. Babinski also reported to the Neurological Society of Paris (June 7, 1900) the case of a girl of seventeen, who presented the signs of infantilism, amenorrhea, abundant fat, scantiness of hair, but without acromegaly. She developed pains in the head with disordered vision, and epileptiform convulsions. After death it was discovered that she had a tumor of the pituitary. It is clear then that there is some relationship between lesions of the pituitary and thyroid glands and genital disturbances. What, then, and where is the primary disorder which leads to such extraordinary anomalies of growth and development? Breton and Michaut have suggested that there is a trophic deviation of the genital activity to the bone marrow so that the medullary bone-forming function preserves its activity indefinitely. The cessation of genital activity would lead to acromegaly. This view is somewhat similar to that promulgated previously by Freund, Klebs, and Verstraeten, who held that there is a disturbance of the evolution of the genital function. If genital evolution is in excess we get gigantism and acromegaly; if defective, we get infantilism and dwarf growth. It is, of course, well recognized that with the onset of puberty the efflorescence of the sexual characteristics is coincident with increased growth and development of the body as a whole. The operation of castration has been observed to exert a notable effect on the stature of the body as

well as in inhibiting the development of the secondary sexual peculiarities. In eunuchs the height is often extreme. This is due chiefly to a disproportionate increase in the length of the legs. Lortet has confirmed this statement by an examination of the skeleton of an Egyptian eunuch 196 centimeters high. In castrated animals, the capon and the ox, the same increased growth of the lower or hind extremities is to be observed. Silva has further recorded a curious observation in a youth who was normal until the age of thirteen. The testes then remained atrophic and when about twenty he began to grow rapidly, eventually manifesting some enlargement of the head and extremities, muscular weakness, anosmia, slight scoliosis, to such a degree as to suggest acromegaly. Of interest, also, in this connection, is a case reported by Sachi, where a boy, the subject of a tumor of the left testicle, attained puberty at the age of five. At nine he was five feet six inches high and weighed ninety-seven pounds. He had a black beard and full sexual development.

While such facts as those just mentioned are suggestive of some relationship between genital dystrophy and disorders of growth and nutrition, to my mind the evidence is not strong enough to induce us to accept the view that deficiency of the genital organs is the sole cause of these disorders. Two-thirds of the cases of acromegaly develop after puberty is practically reached. The loss of sexual power in the male is gradual and progresses *pari passu* with the extension of the disease itself. In the female, too, while amenorrhea is a frequent and often the first symptom of the disease, it is not invariable. Again genital hypoplasia and other signs of infantilism are often present in dwarfs, and the argument might be applied with equal force to explain dwarfism. The same cause could hardly produce at one time dwarfism and at another gigantism. Moreover, while genital hypoplasia has been often observed in cases of thyroid atrophy and gross lesions of the pituitary body, so far as is known castration does not produce a converse effect on these particular organs. While, then, genital dysplasia undoubtedly plays some rôle in osteogenesis, it seems to be quite a subordinate one, and appears to be inadequate to explain the more marked aberrations from the normal path of development. The functions of the thyroid gland, the pituitary body, and the sexual organs are, however, no doubt correlated, and it is probable that the normal course of growth and development is dependent on a certain balance of power exerted by these glands. Of what nature is this correlation we are to a great extent in the dark. It is now generally believed that the glands mentioned produce internal secretions that are essential to the normal course of the metabolic processes. That the correlation is actual and not theoretical is shown in the recent observation that definite histological changes in the pituitary can be demonstrated as a result of pregnancy, in the direction of a hyperplasia of the chromophobe cells and a readjustment of the eosinophiles. It may be inferred that while the metabolic processes referred to are vital in nature, they are inextricably associated with chemical transformations. The importance of chemical substances in the growth of the organism is well illustrated by the experimental work of Wegner, Maas, and Gies. Wegner proved that by feeding rabbits with minute doses of phosphorus for a prolonged period he could get a marked increase in the formation of bone at the epiphyseal sutures of the long bones. The same thing has been found to occur with arsenic. Observations upon the nature of the metabolism in giants are hitherto lacking, but we have considerable evidence to show that in acromegaly metabolism is disordered. There appears to be a tendency to an overproduction of lime salts in acromegaly. Deposits of lime have been found in various parts of the body, especially in the pituitary, the thyroid, and the vessels (arteriosclerosis). Ossiform infiltration of the dura mater has been observed. Von Moraczewski has also demonstrated a tendency to the retention of lime and phosphorus in the system in cases of acromegaly. Not only then is there an increased deposit of lime at the extremities of the bones, but also in widely distant parts of the body.

We are, I think, led to the inevitable conclusion that gigantism, like acromegaly, is very often a disorder of development brought about by abnormal metabolic processes We must also admit that a large proportion of cases of gigantism are etiologically the same thing as acromegaly, and that an additional but uncertain number are probably abortive acromegaly (acromégalie fruste). One consideration must, however, be by no means overlooked in any discussion of the question of internal secretion. The doctrine of internal secretion as at present understood implies the existence of certain substances in the body upon which the secretion of the glands in question may act. Now the gland, thyroid or hypophysis, may be totally unable to perform the duties required of it, owing to some lesion, or it may be only relatively so. In either case similar symptoms would arise. On the one hand, relative inadequacy of a gland will set in as soon as its reserve power has been exhausted, and may increase until it becomes absolute. On the other hand, there may be an excess of the substances upon which the internal secretion is supposed to act. Therefore it is quite possible that certain forms of development disorder may be due to relative inadequacy on the part of some of the important glands, that, as we have seen, are competent to modify nutritive processes. In the case of gigantism, relative inadequacy of the pituitary, or it may be a relative overadequacy, short of producing the regular symptoms of acromegaly, might influence growth so as to bring about excess.

However this may be, and the deduction is alluring, there still remains some small proportion of cases of gigantism which cannot be explained on any of these theories. Such are the cases in which in addition to excessive height there is great strength with perfect proportion. Here there can be no question of disease in the ordinary acceptation of the term. Such giants are examples of the so-called "athletic" habit of body, and are strictly comparable to the giant infants before referred to. They represent the structure of the human body carried to its highest point. They may be regarded as examples of *true* or *essential* gigantism. Infantilism and pituitary dyscrasia cannot explain them. Rather are they to be referred to peculiarities inherent in the germinal cells of the progenitors. This view is supported by the fact that certain anomalies, for example polydactyly, malformations of the genital organs, and congenital hydrocele, are apt to be associated with the increase in size and weight.

ALBERT GEORGE NICHOLLS.

Gigantorhynchus.—A genus of round worms. *G. gigas* passes its larval stages in beetles and becomes an adult in the intestines of pigs. This species has been reported in man. See *Nematoda*. A. S. P.

Gigli, Leonardo.—Born April 30, 1863, in Villa di Quarto in the Commune of Sisto Fiorentino, Italy. He obtained his medical degree in 1889 and the same year was appointed assistant in Chiari's Clinic. For a year (1892–3) he studied with Mikulicz in the Breslau Clinic and while there invented the saw which bears his name. On returning to Florence, in 1894, he was appointed surgeon to the Hospital of Santa Maria Nuova. The operation of hebosteotomy, which he devised, is known as Gigli's operation. He died April 4, 1908. T. L. S.

Gila Monster.—*Heloderma suspectum*, the only lizard known to be poisonous. The poison glands are in the lower jaw, and they secrete a substance which is similar to snake venom in its action. A. S. P.

Gilroy Hot Springs.—Santa Clara County, California.

POST-OFFICE.—Gilroy Springs. Hotel, cottages, and furnished tents. These springs are located on the Coyote River, fourteen miles northeast of the town of Gilroy, and forty-three miles from San Jose, in the Santa Clara Mountains. They are reached by the Southern Pacific Railroad to Gilroy, and from thence by stage or automobile over the picturesque mountain road. The springs lie nestled in among the mountains, surrounded by fragrant forests of spruce and pine. The elevation is 1,240 feet. The temperature averages 71° F. in summer and 57° F. in winter. There are no winds, no fogs, no mosquitoes and no malaria. The atmosphere is rich in ozone, and the climate very genial. There is one main spring, which flows in great abundance. The temperature of the water varies from 108° to 115° F. Anderson's analysis:

ONE UNITED STATES GALLON CONTAINS:

Solids.	Grains.
Sodium chloride	31 75
Sodium carbonate	1.42
Sodium sulphate	.75
Potassium iodide	Trace.
Potassium sulphate	2.16
Magnesium carbonate	2.45
Magnesium sulphate	9.04
Calcium chloride	8.50
Calcium sulphate	2.70
Ferrous carbonate	.26
Ferrous oxide	Trace.
Arsenic	Trace.
Silica	3.31
Organic matter	.52
Total solids	62.86

Gases.	Cubic inches.
Free carbonic acid gas	12.17
Free sulphureted hydrogen	9.25

The analysis shows a light alkaline, sulphureted water. It is used with considerable benefit in syphilis, rheumatism, gout, lead and mercurial poisoning, alcoholism, tuberculosis, in glandular swellings, in chronic skin eruptions, kidney and liver troubles, and bladder and urinary complaints. The water is also used for bathing, for which excellent facilities have been constructed. EMMA E. WALKER.

Gimbernat, Antonio.—Born in 1742. He studied medicine and became a professor in Barcelona from 1762 to 1774 and later a surgeon in Madrid. He was appointed Surgeon-in-ordinary to King Carlos III, and in 1787 founded and became director of the College of Surgeons of San Carlos. He died in 1790. Gimbernat was a famous anatomist, surgeon, and herniologist; his name has been perpetuated through his discovery of the ligament called after him, Gimbernat's ligament. Among his most noted contributions to medical literature are "Nuevo método de operar en la hernia crural," and "Disertacion sobre el recto y abuso de las suturas." E.L.J.

Ginger.—See *Zingiber*.

Gingivitis.—See *Gums, Diseases of the*.

Ginseng.—A name applied to the roots of several species of *Panax* L. highly prized in superstitious Chinese medicine, and chiefly so used, though they have some mild aromatic properties (see *Araliaceæ*). The original Ginseng ("Schin-Seng") is *P. Ginseng* C. A. Meyer, of China, rarely seen in commerce here. The American variety, from *P. quinquefolium* L. (*Aralia q.* Decne), is chiefly exported to China and is bought eagerly, at high prices, by Chinese merchants for that purpose. It used to be very abundant in rich forest lands of the Eastern United States, but has been largely exterminated, except in remote sections. It is of very slow growth and, when well developed, presents two principal branches, and occasionally a small intermediate one. From this peculiar form, it is regarded as effective in determining the sex of the unborn child, whence its high repute in China. It contains considerable gum and starch and a little volatile oil and resin and the peculiar, but apparently inert, sweetish substance *Panaquilon*, soluble in alcohol and water. Obviously, there is no dose for so inactive a drug.

HENRY H. RUSBY.

Giraldès, Cardozo Cazado Joachim Albin.—Was born in Portugal in 1808. He obtained his medical degree in Paris, December 23, 1836. About 1848 he became surgeon to the Hospital des Enfants in Paris, at which place he delivered lectures in surgery until his death on November 26, 1875. Few surgeons of France obtained more fame through brilliancy of mind and skill of hand than Giraldès, hamperds though he was by his smallness of stature and the lose of one eye, due to an accident at an operation. He discovered the paradidymis which has been named after him, the organ of Giraldès. Among his many contributions to medical literature are the following: Mémoire sur la terminaison des bronches, 1839; Des luxations de la mâchoire, 1844; Du degré d'utilité de l'anatomie comparée dans l'étude de l'anatomie humaine, 1846; Observation et description anatomo-pathologique des kystes congenitaux du cou, 1860: Note sur un nouvel organe glanduleux, situé dans le cordon spermatique, et pouvant donner naissance à des kystes, 1859; Des calculs urinaires chez les enfants, 1862; Leçons cliniques sur les maladies chirurgicales des enfants, 1869. E.L.J.

Gizeh.—See *Egypt*.

Glanders.—Farcy, equinia; malleus, malleus humidus et farcinosus; Rotzkrankheit, Hautwurm (German); Morve, Farcin (French); Morvo, Farcino (Italian).

Glanders is an infectious disease characterized by the formation of nodules on the skin, mucous membrane, lungs, lymphatics, and other organs. The nodules have a tendency to break down leaving ulcerations. The bacillus mallei is the causative agent of the disease.

Glanders has been known since the remotest time, it having been mentioned by Hippocrates and also by Vegetius. The name malleus owes its origin to Aristotle. Its infectious nature was recognized by Apsyrtus and Vegetius, although not until the eighteenth century was it generally recognized as an infectious disease. In 1749, Lafosse in presenting "A Memoir of the Glanders in Horses" claimed that the disease is not a blood infection, but represents only a local malady confined to the nasal cavities. His prominent position exerted a great influence on the acceptance of his belief, which lasted for about a half century. In 1784, strict veterinary police measures were enacted by the French Government for the control of the disease, and at that time Viborg regarded glanders indentical with farcy. In 1840, Renault and Bouley at Alfort proved the contagious nature of the disease by successful inoculation experiments, and although even later some conceived the possibility of the spontaneous development of the disease, its infectious nature was no longer doubted. In 1882, Loeffler and Schütz isolated and successfully cultivated the bacillus mallei and about the same time Bouchard, Capitan and Charrin had successfully grown cultures from infected animals with which they succeeded in producing glanders in guinea-pigs, and asses, even in the fifth generation.

After the discovery of the causative agent the disease continued to be the subject of investigation.

Helman and Kalning obtained from the sterilized cultures a product known as mallein which has been and is at present used as a diagnostic agent. In more recent times Schütz and Miessner, Schnürer, Pfeiller, Mohler, and Eichhorn have contributed to the methods of diagnosing this disease with the aid of the agglutination and complement-fixation tests.

Glanders is a very widely spread disease, and with the exception of Australia, has occurred practically in every country of the world. Its spread has been favored no doubt during the infestations of armies of the different wars, and in the French army alone over five per cent. of all horses had to be destroyed on account of glanders every year from 1835 to 1845. At the present time glanders prevails quite extensively in the different countries, although its spread is checked by the effective sanitary police measures and also by the more satisfactory diagnostic methods which we have at our command at the present for diagnosing latent cases of the disease. In the United States the disease is prevalent, especially in the larger eastern cities where the unsanitary and unhygienic stabling conditions are very favorable for the propagation of the disease. Some observers claim that in these cities the disease exists in more than five per cent. of all the horses.

The bacillus mallei is a straight, or slightly curved rod, it is non-motile, from two to four microns long and $\frac{3}{10}$ to $\frac{5}{10}$ of a micron in diameter. The bacillus of glanders is easily cultivated, but thrives only at a temperature above 20° C. and ceases to grow at 45°. The media most suitable for its cultivation should be neutral or slightly acid. Glycerin media is also well adapted for its growth. The cultures grown on solid media have a peculiar slimy consistency. The growth on potatoes in most characteristic. At first small honey-drop-like translucent colonies result which later coalesce into a ropy mass of a dark, almost chocolate color. The bacilli are not very resistant to the influences of external agencies. In decomposing substances they retain their virulence from thirteen to fourteen days. Drying destroys them in from one to two weeks or at the longest in three months. Sunlight destroys them in twenty-four hours, while they resist heat at 55° C. for ten minutes, and for only five minutes at 80°. Secretions from affected animals, also the tissues, lose their virulence within a few days.

Subcutaneous inoculation of cultures or tissue containing virulent bacilli or applying it to the mucous membrane of the nose results in susceptible animals developing typical cases of glanders. The first indication of the disease in such cases is manifested by the formation of nodules which after breaking down ulcerate; the lymph vessels and lymph glands of the neighboring parts also become involved. The disease may also be produced by feeding and some of the recent investigators maintain that in the natural form of infection this mode is the most frequent by which animals become infected.

Asses are the most susceptible, then follow mules, horses, and carnivorous animals. In fact, nearly all warm-blooded animals are susceptible with the exception of cattle, hogs, and white mice. Man, although not as susceptible as solipeds, may become infected either by ingestion or inoculation.

The infection of healthy animals always takes place through the direct or indirect transmission of the bacillus mallei from infected horses. The direct transmission may be through contact of healthy animals with those affected, while indirectly this may be accomplished through the infective organisms after leaving the animals with the excretions remaining deposited where they may be taken up by susceptible animals or men, thus giving rise to the development of the disease.

Infection may take place either through abrasions of the skin or mucous membrane, through the air passages, by inhalation and by ingestion through the digestive tract. Infection through the digestive tract is without doubt the most frequent in horses, and this has been satisfactorily proved by the experiments of Hutyra. Experimental studies on the other modes of infection were also made and established the possibilities of such forms of infection. The fact that glanderous lesions are almost invariably found in the lungs and very frequently the disease is confined to the pulmonary lesions does not point to an infection by inhalation. The infection may readily reach the lungs through the digestive tract without leaving visible traces of infection in other parts. The predilection of the glanders bacillus for the lungs is well-known and McFadyean's statement, that no cases of glanders have been reported in which the lungs were not affected to a greater or lesser extent, is well founded.

The bacilli of glanders are eliminated either with the discharge from the nose or they may be coughed up with the bronchial secretion from the lungs, the virus in such cases remaining active under ordinary conditions for a considerable length of time, and especially in damp, poorly ventilated, dark stables they retain their infectivity for weeks or even months. The discharging cases of glanders are of course the greatest source of danger since such an animal will infect the water supply of a stable, the utensils, and ignorant attendants will not take proper precautions and measures to prevent the spread of the disease in such cases. Frequently sponges are used for the cleansing of the noses of horses with nasal discharges, and in this manner the disease is transmitted to healthy animals or men with relative frequency.

On the other hand, the presence of latent cases of glanders, in which the pulmonary lesions communicate, with the bronchi may also be a continuous source of danger for infection, and especially since this form of the disease may persist in a horse for months, yes, even years without the animal showing any external indications of ill health.

In the presence of cutaneous glanders (farcy) various-sized nodules or ulcers develop on the skin (Fig. 2794). These lesions may appear on any part of the body, but most frequently they are located on the inside of the thigh. The nodules are located in the subcutaneous tissue and after degeneration burst leaving ulcerated areas on the surface of the skin. The tissues surrounding the nodules show a gelatinous infiltration, while the centers of the nodules proper contain a yellowish-gray or red, viscous pus. The lymph vessels around the nodules and ulcers are greatly thickened, cord-like, and the corresponding lymph glands are also indurated and enlarged. In cases of nasal glanders the submaxillary lymph glands are very frequently involved and on cross-section the parenchyma shows one or more purulent foci from the size of a pinhead to that of a pea. In nasal glanders the septum manifests nodular forms or ulcers. In the early stages of nasal glanders the septum shows gray or yellowish nodules of the size of a millet seed which are surrounded by reddened mucous membranes. After the breaking down of the nodules, ulcers develop which as a result of the progressive degenerations become irregular in shape (Fig. 2795). Their base is frequently covered with pus detritus or with a brownish scab. Small ulcers may coalesce and in this manner large areas of ulceration result. The healed ulcers in horses disclose the almost characteristic cicatrix in the form of a radiating scar. These scars, as before stated, being known as the star shaped scars of glanders (Fig. 2796).

The lungs are affected in a large percentage of cases of the disease, and infections here may be primary or secondary. They manifest either tubercle-like or lobular pneumonic areas as the initial lesions. The glanderous nodule is the most characteristic finding in the lungs. These vary in size and appearance in

the same individual. They usually range from the size of a pinhead to that of a bead, shot-like on palpation and do not "shell out" readily from the surrounding tissue (Fig. 2797). In later stages of their development they are found in the centers of small hemorrhagic pneumonic islands. The older nodules are surrounded by firm fibrous capsules. On cross-section

Fig. 2794.—Farcy Affecting the Skin of the Shoulder.

the center is yellowish, caseous or dry and crumbling. Calcareous deposits in old arrested glanderous nodules may occur. These nodules are usually not in great abundance, and often in advanced cases may not number more than forty or fifty in both lungs. Larger numbers, however, are not infrequent.

The microscopic appearance of the glanderous nodules, especially of the lungs, has been the subject of careful study by Pflug, Rabe, Csokor and Le-Clainche, Montane, Schütz, Councilman, Kitt, Nocarde and others. The microscopic appearance of fresh nodules manifests a congestion of the capillary vessels, and the alveoli occluded with red blood cells, fibrin, desquamated epithelia, leucocytes and blood-coloring material. Nodules with necrotic centers showed the alveoli to be filled with fine granular débris, and a very dense mass of broken-down nuclei (Fig. 2798). The outside border of the débris is more homogeneous and contains less broken-down nuclear material than the center. The entire mass of débris lies inside of the alveoli and fills them up in the form of plugs so that the septa of the alveoli are recognizable only in parts and indistinctly. Besides these broken-down masses, round cells are present around the necrotic mass forming a more or less distinct zone of infiltration (Figs. 2799 and 2800). Larger glanderous nodules manifest the same picture; the periphery of the zone of the cellulra infiltration is surrounded by a large cellular fibro-plastic tissue zone which represents the granulation tissue. The fibroplastic proliferation starts from the capillaries of the alveolar septa and the granulation tissue grows into the lumen of the alveoli filling the same. This forms the connective tissue capsule of the glanderous nodules. This, however, may also be subject to necrobiosis and the process again extending to the neighboring lung tissue results in cellular infiltration and granulation in that way forming the extension of the glanderous focus (Fig. 2801).

A catarrhal pneumonic form of glanders of the lungs is manifested in atelectatic areas which have a brownish-red color. In a later stage, however, they break down as a result of a central softening, forming a yellowish caseopurulent mass, and become surrounded by a red hepatized zone, which is very frequently infiltrated with a yellowish gelatinous exudate. In cases where the lungs show an extensive involvement an acute bronchitis is usually present in association with it. The mucous membranes of the bronchi in such cases show nodules or ulcerations besides the usual characteristics of this affection.

Other organs in which changes occur are the spleen and the liver. These quite frequently manifest small translucent nodules which contain either a yellowish pus or a dry mortar-like mass. The nodules in these organs are usually surrounded by a white dense connective-tissue capsule. Nodules of glanders have also been observed occasionally in the kidneys, brain, body musculature, and in the heart muscle. Of the bones, the ribs are most frequently involved, and in these different-sized caverns form, which are filled with a yellowish tenacious substance. The corresponding lymph glands of the affected organs are also usually affected, showing acute swelling in fresh infections, while in chronic cases a dense tough indurated condition is noted.

A differential diagnosis of the nodules becomes very frequently necessary, and in such cases the nodules of anthracosis, metastatic pyemia, malignant tumors, and especially parasitic nodules come into consideration. The nodules of anthracosis are rare. They are

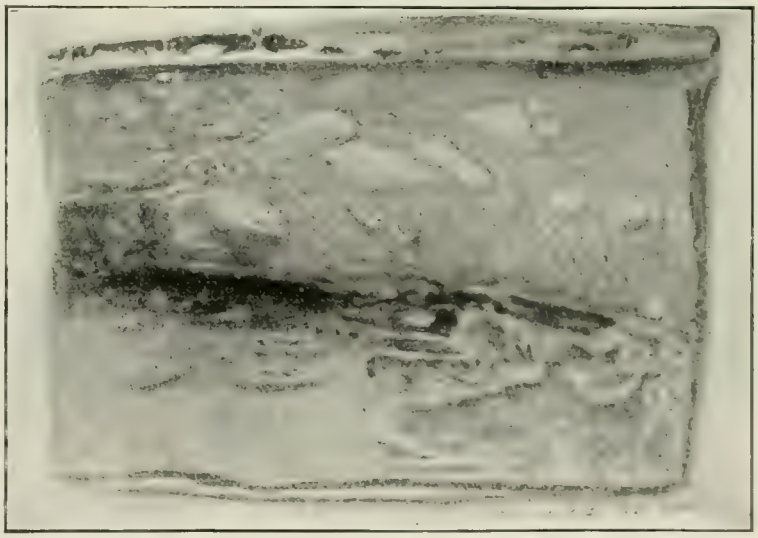

Fig. 2795.—Lesions of Glanders in the Nasal Septum.

small, usually contain pigment, and are composed entirely of fibrous tissue. In metastatic centers of pyemia the pus is more fluid, the connective-tissue wall is thin, the condition is acute, and the primary seat of infection can usually be found. In metastatic tumors there are no fibrous walls surrounding the growth, and on cross-section the tumor cuts easily and

contains no central area of degeneration, but is homogeneous. The primary tumor can be found in some other part of the body. The parasitic nodules caused by the Strongylus arnfieldi and the Ecchinococcus are quite similar to glanders nodules. Parasitic nodules, however, no matter how small, are always surrounded by a capsule. The periphery is translucent and the

Fig. 2796.—Stellate Cicatrix from Nasal Septum. From a case of chronic glanders. (Kitt.)

center usually contains lime salts. In the large nodules the capsule is not thick as in the old caseous glanders nodules.

Nodular multiplex bronchitis, which is characterized by small, uniform, gray, frequently calcified nodules, may be mistaken for glanders. In the presence of this affection, however, the surrounding lung tissue appears normal; besides, the bronchial lymph glands show no involvement. In chronic interstitial pneumonia the inter-alveolar connective tissue is extensively and uniformly thickened and there are no nodules and no gelatinous infiltration is present. In tuberculosis, which is very rare in horses, there are different-sized nodules, some of which resemble sarcomatous growths, and there is also a caseation of

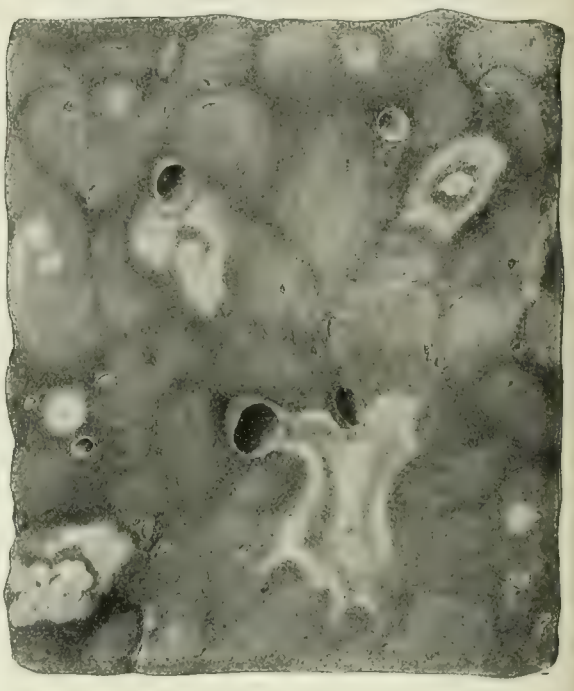

Fig. 2797.—Section of Lung of Horse (Natural Size), showing Nodules and Cicatrices. The lobules are more prominent than is natural. (Kitt.)

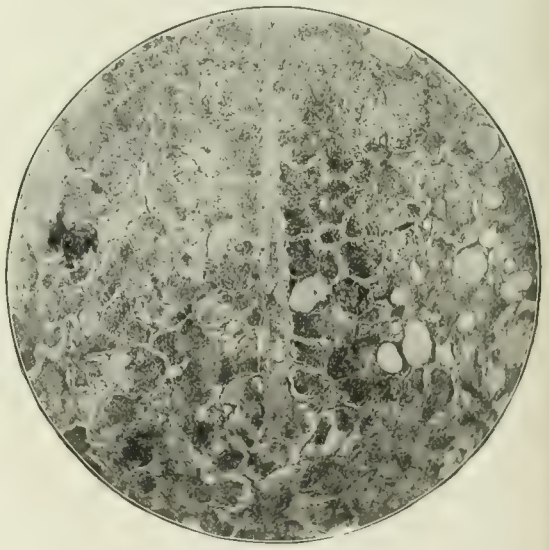

Fig. 2798.—Section of Beginning Nodule Adjoining an Interlobular Septum in Horse's Lung. The darker central portion is composed of cellular and nuclear detritus. The walls of the alveoli are necrotic.

the thoracic lymph glands. In botryomycosis and pneumomycosis the changes show a more chronic character, and in these infections a microscopical examination will readily disclose the character of the affection.

The time of incubation usually depends on the manner and on the intensity of the infection. Artificial infections may be followed by the appearance of

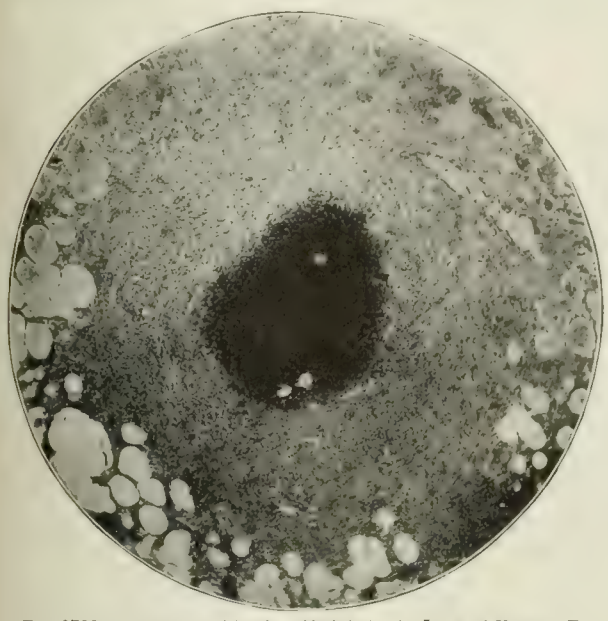

Fig. 2799.—Section of Glanders Nodule in the Lung of Horse. The dark central mass is composed of cell and nuclear debris in which no lung structure can be recognized.

symptoms in from two to three days. After natural infections, however, several weeks and sometimes months may elapse before external indications of the disease are manifested.

The pulmonary form of the disease develops very insidiously and the progress of the disease may be very slow, and again it may take on an acute form from the onset in which case death may result from a glanderous pneumonia. This form is observed from time to time in horses. The existence of the disease of the lungs is sometimes indicated by frequent nose-bleeding as a result of destructive pulmonary processes. In the nasal form the first appearance is indicated by a catarrh which is followed by unilateral or bilateral serous discharges, which later become purulent and frequently contain streaks of blood. The mucous membrane of the septum soon shows a formation of gray or yellowish nodules of the size of a hemp seed which break down leaving ulcerations with well-defined borders which after spreading assume ragged outlines and a raised border. They may also be present on the turbinated bones, in fact, in all parts of the nasal cavity, including the larynx and trachea. The ulcerations may become aggravated and may be accompanied by extensive destruction of the deeper tissues, resulting very frequently in perforations of the septum. At other times the ulcers may heal leaving the characteristic cicatrices, already described.

In the cutaneous form of the disease, the nodules may develop on any part of the body, in the skin or subcutaneous connective tissue, which break down and leave ragged ulcers. The discharge is a viscous, yellowish-gray pus, which at times is intermixed with blood. The region of the nodules and ulcers of the skin and subcutaneous tissue and the lymphatics show a marked thickening and the regional lymph glands also show induration. Around the nodules there is an infiltration of the surrounding subcutaneous tissue which may spread over a large area resulting in extensive doughy painless swellings. In horses the swelling appears usually on the lower abdomen and on the extremities.

Constitutional symptoms usually accompany the disease, varying in severity in accordance to whether the disease runs an acute or chronic course, and also whether the manifestations are in the skin or in the internal organs, especially the lungs.

The bacilli may break into the blood at any stage of the disease causing a septicemic affection. Mixed infections have also been observed at times in man in which cases usually the streptococci are associated with the glanders bacilli.

The disease in man is manifested either in the form of acute or chronic glanders, or acute or chronic farcy. When the acute form does not cause death in three or four weeks the patient may linger on with the chronic form showing itself by more or less active lesions which may heal, but usually reappear in different parts of the body. The symptoms in the acute form are a high fever, chills, headaches, and pains in the limbs. These may remain the only manifestations for a week or longer when a cutaneous rash appears in the form of nodules which rapidly break down into ulcerations. Frequently this rash is not visible until shortly before death when the patient dies from acute septicemia after the manifestation of local lesions.

The lesions are frequently accompanied by erysipelatous conditions in different parts of the body, principally, the nose, lips, cheeks, and forehead which show swellings and discoloration. The external lesions usually develop on these parts.

Diagnosis.—This is rather difficult in human beings since manifestations in the early stages are not characteristic The appearance of pus in the subcu-

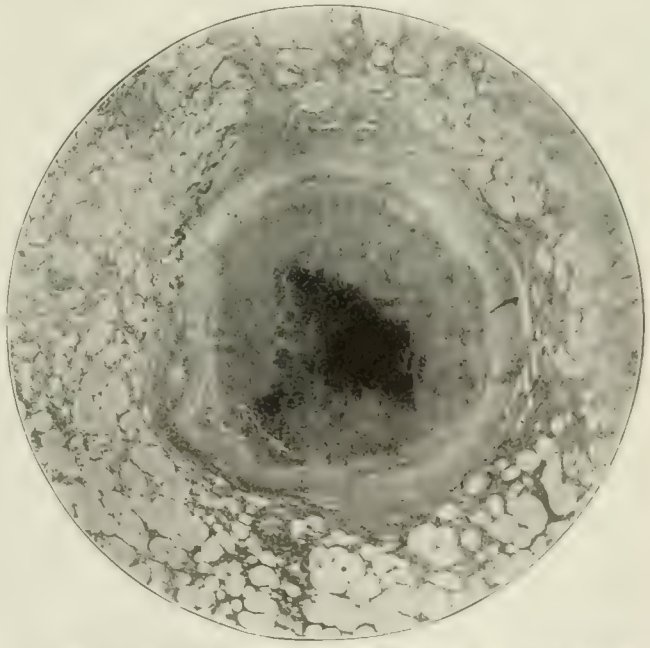

Fig. 2800.—Section of Chronic Glanders Nodule in the Lung of Horse, less advanced in its formation than Fig. 2799. In the center of the nodule the lung structure is still visible.

taneous lesions should be utilized for microscopic examination and in doubtful cases animal inoculations should be resorted to.

Diagnosis by Guinea-pig Inoculation.—This method

was first suggested by Straus, and is often termed "Straus's guinea-pig test for glanders." It is a simple and valuable means of diagnosing those cases of glanders showing farcy buds or a nasal discharge.

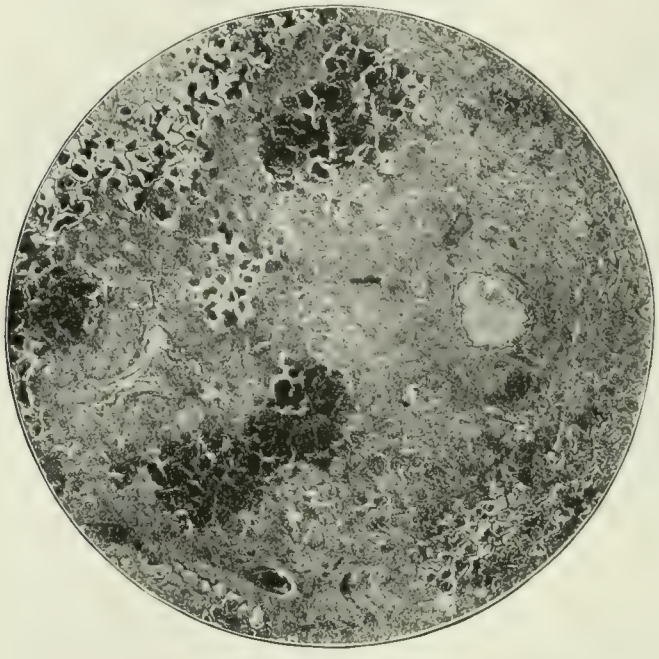

Fig. 2801.—Section of a Diffuse Acute Nodule Showing Several Centers in Lung of Horse.

Although it is usually done at a laboratory, this is not essential, as any veterinarian, with the usual precautions, can apply the test in his office. It is only necessary to have one or two male guinea pigs and an ordinary hypodermic syringe. The nasal discharge is collected on a cotton swab and emulsified with boiled water, so that it can be drawn up into the syringe. The guinea pig is turned over on its back by an assistant, the hair is clipped with scissors from a small area on the abdomen, and the part washed with an antiseptic solution. The needle of the syringe is then pushed through the abdominal wall and a few drops of the material injected. The second guinea pig is treated in the same way. Two are inoculated to guard against one dying of peritonitis before the glanders lesions have had time to develop. It is better to allow the animals to live for from three to four days after the inoculation before chloroforming, unless by examining the testicles they are found to be enlarged and the skin covering them hot and reddened, in which case they may be killed at once. The characteristic lesions of glanders are found in the testicle and consist of the thickening of the tunica vaginalis and adhestions between the latter and the testicles. When these are forcibly separated the surface of the testicle is found to contain small white purulent areas. From such a testicle the organisms of glanders can usually be grown in pure culture. Where such changes are found in a guinea pig it is proof that the horse is affected with this disease.

In all cases where there is the slightest suspicion of the existence of the disease in man, the up-to-date method of serum diagnosis should be employed for diagnosis or elimination.

For the diagnosis of the disease in animals various methods have been devised. The oldest allergic method is the mallein test which is at the present time one of the most valuable means by which glanders may be diagnosed in animals.

Kelning, a Russian veterinarian, discovered mallein, a toxic substance obtained from the cultures of the bacillus mallei. Like tuberculin, when this product is injected subcutaneously into an infected animal, it results in both a general and local reaction, the general reaction manifesting itself by dullness, inappetence and fever, while the local reaction is indicated by large painful edematous swellings at the point of injection from which the lymphatics radiate in the form of hard cords. The mallein produces a febrile reaction only in sensitized animals. A rise of temperature in such animals is characteristic. This begins in from four to eight hours after the injection, and the maximum temperature is reached in from ten to twenty hours with a gradual return to normal. The difference between the before and after temperatures should be at least 2.5° F. to constitute a positive reaction. In the presence of a marked local reaction, however, it is not necessary to have the temperature rise to the height given above.

More recently the ophthalmic mallein test has gained in favor because of its simpler application. The concentrated mallein is applied into the conjunctival sac of the suspected animal with the aid of a camel's hair brush or a glass rod and in the existence of [the disease the treated eye develops a severe purulent conjunctivitis with or without a marked swelling of one or both of the eyelids (Fig. 2802).

The characteristic manifestations of a positive reaction occur in from five to six hours and last thirty-six to forty-eight hours. A purulent secretion or discharge with reddening of the conjunctiva alone is significant of a positive reaction. Swelling and gluing of the lids may be seen in severe reactions. The eye should be examined in a good light sixteen to eighteen hours after the application of the test.

Generally the positive reaction is not accompanied by rise of temperature or systemic disturbances. A

Fig. 2802 —Ophthalmic Mallein Reaction in Glanders.

variation in temperature does not occur in negative tests or normal animals. Occasionally, however, affected horses are hypersensitive, so that often a trace of mallein which enters the circulation produces fever. Accordingly, it is advisable to accom-

pany the ophthalmoreaction with temperature measurements. For this purpose the temperature should be taken twice, the first time when the eye test is being made and the second time when it is judged. In a doubtful eoe reaction where there is an increasing temperature over 101.5° F., the test should be considered positive if the animal ead a normal temperature at the time the test was made. If the result of the test is negative or questionable twenty-four hours after the first application the test may be repeated at once on the same eye or the control eye.

The intensity of the ophthalmic test bears no relation to the stage of development of the infection.

For a practical test to be used by veterinarians on horses the ophthalmic method is without doubt the most satisfactory since it is simple in its application and can be rapidly applied to a large number of animals. There is no reference indicating that this form of diagnosis has ever been employed on human beings, but from its characteristic appearance in animals it should be likewise effective in human beings.

Various authors have advised the cutaneous mallein test for the diagnosis of glanders. This, however, affords no advantages over the subcutaneous or ophthalmic methods. The reaction consists in an edematous thickening of the skin which varies in accordance with the intensity of the reaction.

Serum Diagnosis.—The opsonin, conglutination, and precipitation tests have been employed experimentally for the diagnosis of glanders. The first two proved laborious and impracticable and the latter unreliable.

Of the serum tests for diagnosis, the agglutination and complement-fixation have without doubt proven the most reliable and constitute at the present time the best laboratory means of diagnosing the disease.

The agglutination test was first suggested by McFadyean. Later extensive work was done on this subject by Schütz and Miessner. They used the dead cultures of the bacillus mallei with the sediment macroscopic method, while McFadyean employed the hanging-drop microscopic method.

In this country the most extensive work in diagnosis by the agglutination test was carried out by Moore and Mohler and Eichhorn. In using this method of diagnosis it is important to have suitable strains of glanders bacilli and the best results are obtained with a combination of several strains. The test fluid is prepared in the ordinary way by washing agar cultures after they have been heated to 60° for two hours. The fluid from the culture tubes is collected in flasks and a proper dilution made by comparison with a sample of well-known agglutinating test fluid as to its density.

Dilutions are then made of the sera to be tested with carbolized salt solution in amounts to represent from 1 to 400 to 1,000 to 4,000 or over. The 1 or 2 c.c. of test fluid used is to be considered in the calculation of the dilutions. The same quantity of test fluid is added to each tube. After the dilutions the rack containing the tubes is placed in an incubator for twenty-four hours and then allowed to stand at room temperature for twelve hours when the reading is made.

A more convenient way and one which at the present is practised with good satisfaction consists in keeping the racks containing the different dilution tubes in an incubator for one-half hour only when they are centrifugalized for ten minutes in a centrifuge making from 1,500 to 1,600 revolutions per minute. After removal they are allowed to stand for one and one-half hours, when the results are read. These results can be seen perfectly by taking the stand containing the tubes and holding it up toward the light of the window to see the bottom of the test-tubes. The appearance of an irregular, veil-like clumping at the bottom of the tube with a clearing of the upper part of the fluid indicates an agglutination, while the collection of a dense white precipitation at the bottom of the tube and a cloudiness of the upper part of the fluid indicate failure of agglutination.

After extensive experience with the agglutination test, Schütz and Miessner established the following rules to serve as guides in judging the results of the agglutination test:

1. All animals suspected of being affected with glanders should be subjected to the agglutination test.

2. All those horses should be destroyed in which the blood shows an agglutination of 1,000 and over.

3. All horses should be destroyed in which the blood shows an agglutinating value of from 500 to 800 and which at the same time show clinical manifestations of glanders.

4. All other horses in which the blood shows an agglutinating value from 500 to 800 should be isolated and destroyed only in case the agglutinating value changes on the second examination.

5. All horses in which the blood shows an agglutinating value of 500 to 800 should be considered free of glanders when the agglutinating value remains unchanged on the second examination.

6. If the presence of the disease has been established in a stable, the blood of all horses should be retested at the end of the third week.

Malleinization of the horses shortly before the blood is taken for the agglutination test, influences the results of the test often to a great extent, and therefore it is absolutely essential not to attempt to make the agglutination test in cases where the mallein test has just been made. Ten days to two weeks should elapse before the blood should be taken for the agglutination test from horses which have been tested with mallein.

Complement-fixation Test.—In 1909 Schütz and Schubert published the results of their important work on the application of the method of complement-fixation for the diagnosis of glanders. And since their experiments were followed by splendid results, exceeding by far the results obtained from either the mallein or the agglutination test, they recommended that this method of diagnosis in combination with the agglutination test be taken as the official test in Germany. This method, overcoming as it does the disadvantages of the mallein and agglutination tests, constitutes without doubt the most reliable method for the diagnosis of glanders which we have at our command at the present time. The complement-fixation test is, in fact, the most definite method known for determining specific infections and is as nearly perfect as a biological test can be. It has recently been thoroughly studied by this bureau and has given excellent results.

The principle of this test is presented in the phenomenon of hemolysis, which was first discovered and studied by Bordet and Gengou, and extended by Ehrlich, Morgenroth, and Sachs. It is called the complement fixation test on account of the fact that the complement has been fixed by the combination of antigen with antibody and thus prevented from participating in the hemolytic process in which its presence is essential in order that hemolysis may take place. By this method even small quantities of glanders amboceptors (antibodies) can be demonstrated in a serum.

The presence of the specific immune bodies (bacteriolytic amboceptors) in the serum of glandered horses brings about the fixation of the complement when the antigen in the form of glanders bacilli extract is added to the hemolytic system. The serum of glandered horses, therefore, contains antibodies (immune bodies) against glanders bacilli, which are specific only for the glanders bacilli and for no other infection. The complement-fixation accordingly represents a specific test, as only in the presence of the glanderous immune bodies and glanderous antigen will the reaction take place. If, instead of the glan-

derous immune bodies, other antibodies of another infectious disease be present in the blood serum, they will exert no effect whatsoever on the glanderous antigen; and, on the other hand, if serum containing glanderous immune bodies is brought in contact with an antigen of another infectious disease it will also have no effect on the reaction. By this fixation of the complement the hemolytic system is left incomplete, and as a result no hemolysis will take place. This fixation of the complement by the antigen and immune bodies of glanders in horse serum constitutes the diagnostic test for this disease.

The results of the complement-fixation test should be interpreted as follows:

1. Horses in which the serum produces a complete fixation of the complement in the quantities of 0.1 and 0.2 c.c. should be considered as glandered.

2. Horses in which the serum gives a complete fixation in the quantity of 0.2 c.c. and an incomplete fixation in the quantity of 0.1 c.c. should likewise be considered as glandered.

3. Horses in which the serum produces an incomplete fixation of the complement in the quantities of 0.1 and 0.2 c.c. should also be considered as glandered.

4. Horses in which the serum shows no fixation of the complement in either tube should be considered free of glanders.

In order to reduce the possibility of error to a minimum the agglutination test may be applied to the latter cases, and if this shows a value of 1 to 1,000 or over, the animal should be considered as glandered. However, such cases are extremely rare.

Of the laboratory methods of diagnosis the combined complement-fixation and agglutination offer the best advantages and with their aid glanders can be readily diagnosed in animals and man. Furthermore, the disease in animals could be well controlled by the application of these tests on horses suspected or exposed to the disease. The gratifying results obtained in the eradication work of glanders in Prussia is entirely due to the application of the combined complement-fixation and agglutination tests in all stables where the disease has appeared or has been suspected.

The complement-fixation may also be employed with satisfaction for the diagnosis of the disease in man. Its efficiency for this purpose has been tested by the writer on two positive cases and on several that were negative. Carnivorous animals suspected of glanders were also tested by this method and the results were uniformly satisfactory. Thus, in an outbreak of glanders among lions and tigers of a circus the disease was satisfactorily diagnosed and eradicated by this method.

Prognosis.—The prognosis in man, as well as animals, is always unfavorable, although there is no question but that chronic cases of glanders or farcy may recover; the acute forms, however, almost invariably terminate fatally. The character of the encapsulated calcified glanders nodules of horses which are found on postmortem appear to indicate that recoveries from slight infections of equine glanders are not so very infrequent.

Treatment.—No satisfactory treatment is known. The skin should be treated in accordance with the principles of surgery. The abscesses and ulcers should be swabbed out with strong antiseptics and properly dressed. The nose should be washed out with mild antiseptics followed by insufflations of iodoform or aristol.

Repeated injections of very small doses of mallein have been tried in infections of man with apparently good results. Other methods of vaccine therapy, while extensively carried out on animals, have not been used on human beings.

Glanders in animals, especially in horses, is not treated since the danger of infection from such an animal to others is too great to make any attempts in this direction permissible. Accordingly, it is aimed to control and possibly eradicate the disease by the destruction not alone of all clinical cases of the disease, but also the latent forms which without doubt are responsible in a great measure for the propagation of the disease. Unless the latent forms of the disease are diagnosed and are eliminated as possible sources of spreading the disease it cannot be eradicated. With the present means of diagnosis, however, it is possible and would require only stringent sanitary police measures and the proper execution of the same to control and eradicate the disease.

Immunization experiments which have been made repeatedly with dead cultures of the glanders bacillus prepared in various ways and also with mallein have proved unsatisfactory. The writer hat attempted to immunize by this means, but the vaccinated animals failed to show an increased resistance as compared with other untreated animals.

Adolph Eichhorn.

Glands.—The term gland is loosely applied to some organs that are, strictly speaking, not true glands. In a strict sense, a gland is an organ of epithelial structure, the cells of which form a substance which is a secretion, if it is to be further used by the body, and an excretion, if it represents waste products that are to be eliminated. The ovaries and testes, in addition to forming a secretion, also give rise to cells (ova and spermia) that pass out with the fluid and are classified as *cytogenic glands*. Under the same head Minot classifies certain of the ductless organs, so-called glands, as the thymus, spleen, lymph nodes, hemolymph nodes, tonsil, and bone-marrow. These organs form blood cells which are not to be considered as secretion or excretion products. Although the lungs do not directly secrete, they have the structure of true glands, are developed like them and assist in the passage of oxygen to the blood and carbon dioxide and organic gases from the blood. The latter might be looked upon as an excretion.

Most of the glands are offshoots, or derivatives, of mucous membranes and the great majority still retain their connection, in the completed condition, with the surface from which they are derived; others became disconnected or isolated (hypophysis, thyroid, parathyroid) while a few develop independently of a mucous membrane (adrenal, epiphysis).

These organs vary greatly in size from the liver (40–60 ounces), to the parathyroid (0.1 gram), but in general the structure is about the same.

Glands are classified under two great divisions, *externally secreting*, or those with *ducts*, and *internally secreting*, or *ductless*. In the former class belong those glands in which the fluid, resulting from the cellular activity in the secretory units, passes out of the organ through a series of ducts or tubes, simple or complicated. To the latter class belong those glands that are unprovided with ducts. In these the secretion is taken up by either the blood capillaries or the lymph channels, or both. The externally secreting glands comprise those connected with the alimentary, respiratory, genito-urinary tracts and the skin. Their secretion is of a liquid nature, with the exception of ovary and testes, which also pass out cells (ova and spermia).

As these glands differ greatly in structural form, they have been divided into (1) *tubular*, (2) *tubulo-alveolar*, (3) *racemose*. The *goblet cells* of the alimentary and respiratory tract are considered independent *unicellular glands*. The *tubular glands* comprise the (*a*) *simple*, or mere test tube-like depressions, as in the cardiac end of the stomach and throughout the intestines; (*b*) *coiled*, a long slender tube the lower end of which is coiled upon itself, as in the sweat and ceruminous glands; (*c*) the *branched*, in which the

secretory, or lower part, consists of several short tubes that lead into a common duct, or excretory tube, as the pyloric, duodenal, prostatic, and uterine glands; (*d*) *compound*, or those glands in which the secretory tubules are very great in number and the duct system highly developed, as the liver, kidneys, testicles, lacrimal and mucous, salivary, respiratory, and genito-urinary glands.

2. *Tubulo-alveolar glands* are those with a more or less highly developed duct system and with secretory units that are both tubular and saccular as the submaxillary, sublingual and mammary glands and the lungs.

3. *Saccular glands* are (*a*) *simple*, or those consisting of merely sac-like offshoots of the epithelial surface, as the small sebaceous glands; (*b*) *compound saccular*, or those with a well-developed system of ducts and secretory units all of the saccular type, as the pancreas, parotid, and large sebaceous glands.

As the secretion of the different salivary glands varies, these organs are classified as *serous*, *mucous*, and *mixed*. The *serous glands* are those that give rise to a thin albuminous secretion, as the pancreas and parotid and a number of small unnamed glands. The secretory cells are smaller than those of the mucous type and are somewhat pyramidal in shape and stain deeply with ordinary protoplasmic stains. *Mucous glands*, as the esophageal, duodenal, and small unnamed salivary glands and including glands of the respiratory and genito-urinary systems, give out a thick viscid secretion. The secretory cells are larger and of a more columnar type and stain lightly with the ordinary protoplasmic stains. *Mixed glands*, as the submaxillary and sublingual contain both serous and mucous secreting units, have a mixed secretion and have lightly and darkly staining secretory units.

Although the general structure of all glands is about the same, there are variations according to function. Each is surrounded by a *capsule* of white fibrous tissue that sends in septa dividing the organ into large divisions called *lobes* and smaller ones called *lobules;* the latter represent the structural units of the gland. The lobules are completely separated from one another (except in the liver) by the interlobular connective tissue, this sends in bands that form a meshwork in which are supported the secretory units that may be of the tubular or saccular type, or both. The capsule and interlobular tissue serve to hold the whole together, to connect the glands to the surrounding organs, and to support the larger blood-vessels, nerves, lymph channels, and ducts. The intralobular connective tissue consists of *reticulum* and supports the vascular capillary plexuses and terminal nerve fibers and supports the secretory epithelium. The *secretory units* consist of a single layer of columnar and pyramidal cells (different in liver, adrenal, and others) that rest upon a basement membrane and empty their secretion into a central space, or *lumen*, that connects with the smallest divisions of the duct system. In other words, the gland is a mucous membrane in which the tunica propria is represented by the intralobular connective tissue. From each secretory unit passes a fine duct, lined by low simple epithelium, that joins others within the lobule to form a few ducts (intralobular) that empty into the interlobular ducts that lie between the lobules. These, in turn, empty into larger ducts between the lobes and these latter join to form a single duct for the gland. The epithelium of the ducts varies from simple to stratified columnar in the larger ducts. These cells rest upon a basement membrane that is supported by a tunica propria. In the larger ducts a muscle coat and a fibrous coat are also present.

The large arteries pass through the capsule and in most glands there is a definite place, the *hilus* at which this occurs; the vessels then divide into branches that follow the interlobular partitions and ultimately reach the lobules. Here they form capillary plexuses within lobules around the secretory units and then pass over the venous capillaries that return the blood to venules in the interlobular septa. From here the blood is collected by larger vessels and ultimately emerges from the hilus by, usually, a single vein. Capillaries are also seen in the ducts and interlobular tissue. The cells receive their nutrient material and oxygen from the lymph that bathes them; the *lymph* is derived from the blood-vascular capillaries and, in addition, takes up the waste products of the cells and carries these products into the closed lymphatic capillaries that empty the lymph into larger vessels. These ultimately take the lymph from the organ, usually at the hilus. The *nerves* are both vasomotor and excitoglandular. The *vasomotor* pass to the blood-vessels and end in the muscular coat and are vasoconstrictor and vasodilator. The *excitoglandular* nerves pass from the hilus to the interlobular septa, enter the lobule and terminate between the glandular cells. They are of two kinds, *trophic*, that by excitation cause increased production of secretion products within the cell, and *secreting fibers*, that cause a rapid discharge of the secretion from the cells.

In addition to general characteristics of glandular cells, some contain minute channels by which the secretion enters the lumen of the duct system. In the liver cells these *secretory canaliculi* empty the bile into the bile capillaries. These canaliculi have been found in the parotid and other serous glands, between the cells and in the demilunes of Heidenhain of the salivary gland, the acid cells of the stomach and between the alveolar cells of the pancreas.

During the periods of rest and activity the glandular cells differ in appearance. These cells also differ in shape in the various glands, as in the saccular glands they are pyramidal, in the tubular gland, cuboidal or columnar, while in some others as the liver and sebaceous glands, they are polygonal. The *goblet cell*, a *unicellular gland*, varies from an irregular column, in the empty state, to the form of a goblet, when filled with mucin.

All glandular cells consist of a more or less granular protoplasm containing a nucleus and centrosome. The position of these last two structures and the nature of the protoplasm depend upon the state of activity of the cell. All secreting cells contain granules, whether serous or mucous, but they differ in these two kinds of glands in size, number, chemical composition, and stain reaction. The granules of the same cell may vary also, representing different stages of development. In the early resting stage, the nucleus lies near the center of the cell surrounded by evenly distributed granules. The cell itself is slightly smaller. As secretory activity begins, fine granules begin to appear and these gradually become increased in size and number to the ripe stage and then the appearance of the cells changes. The granules migrate toward the lumen end of the cell occupying the bulk of the cell, while the nucleus is forced to the basal zone and is surrounded by clear or only finely granular protoplasm. At the height of secretory activity, the granules and fluid are expelled into the lumen of the saccule or tubule and the cell returns to a period of rest and accumulation of granules. If secretory activity be stimulated, all of the granules leave the cell, and without a period of rest the granules cannot form and accumulate, so the protoplasm is clear. The granules of mucous and some other gland cells are not seen in tissue fixed and stained by the ordinary methods, as the water of the fixing agents and even alcohol causes these granules to swell and go into solution. To study them osmic acid vapor or a mixture of equal parts of five per cent. osmic acid and saturated potassium bichromate solutions, or a saturated picric acid solution should be used for fixation.

In *goblet cells* the granules accumulate in the

peripheral half of the cell only. The nucleus lies in the basal half surrounded by a clear protoplasm. The mucin granules, at first small, become gradually larger and respond well to the special mucin stain. As they increase in size and number, the part of the cell they occupy becomes swollen to the form of a goblet. When fully distended, the granules pass out of the cell, probably through the flooding of the cell with the watery portion of the lymph. They swell immediately and become dissolved to form a mucous plug. The empty cell exhibits a delicate reticular structure in the former mucous area and this gradually refills and repeats the process.

In *serous glands* there is less disturbance of the form of the cell. This process of extrusion of the secretory granules seems to be an exciting cause of the formation of new granules and the ever recurring cycle continues during normal conditions. If excessive secretion be induced, then the discharge becomes more rapid and the protoplasm is soon deprived of all of the granules; as a result the secretion will become altered and the gland will require a longer period of rest to recuperate. The origin of the secretion granules is not quite clear, yet there seems to be good reason to believe that, in some glands at least, they arise from the mitochondria. The nucleus seems to be connected with the secretory activity of the cell. During the time it undergoes enlargement indicating an excess of metabolic activity. It seems to extrude part of its chromatin into the neighboring protoplasm and this material apparently goes into the formation of secretory granules. The chromatin may remain as an independent mass, consisting of granules or threads, and constitutes then a *paranucleus*.

Excretion is the process by means of which substances that represent waste or end products of metabolism are removed from the body. These products, if retained too long, would produce a harmful effect, hence their early removal is necessary. The organs of excretion are the kidneys, that form the urine; the sweat glands, that form perspiration; the liver, that excretes cholesterin and lecithin in the bile and forms the urea, that is eliminated by the kidneys; the lungs, which remove the carbon dioxide and organic matter. These organs are all true glands, have ducts, and the cellular activity during the process of excretion is analogous to that during the act of secretion.

Internal Secretion.—The glands that give rise to an *internal secretion* are the thyroid, parathyroids, adrenals, pituitary body, pineal body, carotid and coccygeal glands, areas of Langerhans of the pancreas, interstitial cells of the testicle and corpora lutea of the ovary. These organs belong to the ductless variety as they possess no regular outlet for their secretion. In what manner the secretion leaves is unknown, but it must be by way of the blood-vessels or lymph-channels, or both. In this way the products of cellular activity are carried to the organs requiring them, and as long as the secretion is normal in quantity and quality, they maintain a certain balance, especially nutritive. If the nature or quantity of the secretion be altered, this balance is disturbed, and certain symptoms exhibited, indicated the disturbance of certain glands. The function of each gland is determined by the symptoms exhibited, when it is diseased or removed, experimentally or for disease, and by the administration of its extract for experimental purposes.

Glandular activity is controlled by nerve centers located in the central nerve system. All normal secretion is a reflex act. Secretion may be caused by the stimulation of these centers, by impressions made upon the peripheral terminals of afferent nerves, by emotional states, or by changes in the composition of the blood. The nerves are from the cerebrospinal and sympathetic systems. Some claim the two distinct *efferent*, or *excitor* nerves are required, *trophic*, that stimulate the production of organic constituent, and *secretor*, those that stimulate the secretion of water and inorganic salts. The internally secretive glands have a more intimate sympathetic connection than the externally secreting glands.

H. E. Radasch.

Glandulæ Suprarenales Siccæ.—Desiccated Suprarenal Glands. "The cleaned, dried, and powdered suprarenal glands of the sheep (*Ovis aries*) or ox (*Bos taurus*), freed from fat." (U. S. P.) As soon as the animal is killed the glands are removed, separated as far as possible from the surrounding fat, and dried in a current of warm air. When dried they are coarsely powdered and the fat is dissolved out by benzin. They are then dried again and reduced to a fine powder. The resulting product is a light yellowish-brown amorphous powder, one part of which represents five or six parts of the fresh glands. "If 0.5 gram of desiccated suprarenal glands be macerated with 25 c.c. of water for fifteen minutes and filtered, the filtrate should give an emerald-green color upon the addition of a few drops of ferric chloride test-solution. The green color disappears quite rapidly." (U. S. P.)

It has been employed externally as a hemostatic and internally in Addison's disease. The dose is gr. iii.–v. (0.2–0.3). The preparation is, however, little used in medicine, preference being given to the various liquid preparations of the suprarenal gland known as adrenalin, suprarenin, suprarenalin, epinephrin, etc. T. L. S.

Glandulæ Thyroideæ Siccæ.—Desiccated Thyroid Glands. "The cleaned, dried, and powdered thyroid glands of the sheep (*Ovis aries*), freed from fat." (U. S. P.) This preparation is made in the same way as the similar one of the suprarenal glands. It is a yellowish amorphous powder containing the active ingredients of the thyroid gland, one part of which is equivalent to about five parts of fresh thyroid tissue. If one gram of desiccated thyroid glands be mixed with an equal weight of pure sodium hydroxide and carefully fused in a silver dish, and oxidized by adding potassium nitrate while fusing until a white mass remains, and if the fused mass be dissolved in a small quantity of water, the solution treated with 2 grams of sodium nitrite, acidified with concentrated nitric acid, and then shaken with 5 c.c. of chloroform, a decided pink to violet coloration should be imparted to the latter (presence of iodine compounds). (U. S. P.) This preparation is largely used when thyroid medication is indicated, in doses of gr. i.–x. (0.06–0.6). See *Organotherapy*. T. L. S.

Glandular Fever.—*Synonyms:* Drüsenfieber, fièvre ganglionnaire.

Definition.—Glandular fever is an acute infectious disease of childhood, characterized by sudden onset, fever, swelling of the cervical lymphatic glands, and constipation; but there is no exanthem. It is probably contagious.

Etiology.—The cause of the disease is unknown. It has been suggested that the tonsil or pharynx may be the portal of entry for the infectious agent, whatever it may be; but there seems to be no discoverable local lesion. Another theory is that the infection finds entrance through the intestines; and some color is lent to this theory by the suggestion that it might possibly explain the fact that the left cervical glands are the ones chiefly affected, since the infection might spread to them from the thoracic duct. It is essentially a disease of childhood, most, but not all, of the cases occurring before the tenth year. A case of glandular fever occurring in a young lady twenty years

of age was reported by Mayer of New York in the *Medical Record* of August 11, 1900. The winter months of the year seem to be the most likely time for the disease to be contracted; and previous diseases, general malnutrition, and lowered vitality act as predisposing causes. Sex seems to have no bearing upon the etiology.

The first account of the disease is probably that by Filatow of Moscow in 1885. Four years later E. Pfeiffer described the disease, and drew attention to the fact that it was apt to occur in circumscribed epidemics; he also noted that where one child in a family suffered from the disease, the others were very liable to suffer too. In December, 1896, Park West published an account of an epidemic in eastern Ohio from 1893 to 1896. The cases were ninety-six in number, and occurred in forty-three families. They were all in the practice of Dr. F. A. Korell of Businessburg, O., and were reported by him in a paper read before the Belmont County (Ohio) Medical Society on April 27, 1896.

This is probably the largest epidemic yet noted, and West's article, besides giving statistical tables, provides an extensive bibliography.

Symptoms and Course of the Disease.—The period of incubation probably lasts from about five to eight or ten days; and during this period there are no symptoms. The onset is sudden, and is accompanied by pain and tenderness in the neck, both of which are made worse by moving the head. Fever is an early symptom, and is apt to be of the remittent type; as a rule it is only of moderate degree, the body-temperature running from 101° to 103° F., occasionally to 104° F. There is no rash, but the face may be flushed in the early stage of the disease. Nausea, anorexia, constipation, and abdominal pain are apt to occur. Inflammation of the throat and pharynx are present; and dysphagia is marked. The lymphatic glands are enlarged and some of them can be easily palpated; this is particularly noticeable in the cervical and carotid regions just below and near the anterior border of the sternocleidomastoid muscle. The swollen glands with the accompanying pain and tenderness are generally found on the left side.

The posterior cervical, axillary, and inguinal glands may become similarly involved. The mesenteric glands may also be affected; and abdominal tenderness, with enlargement of the spleen and the liver, is present. The fever abates as the adenitis reaches its height, and the latter may last for a couple of weeks while the fever remains only a few days. In the Ohio epidemic the average duration of the disease was sixteen days. The most serious complication is nephritis. Suppuration of the glands is rare, and is treated by incision and drainage.

"In two cases in which the general symptoms were severe, Moussous observed the onset, on the third or fourth day of illness, of cough which occurred in paroxysms ending in vomiting, but without the characteristic whoop or glairy expectoration of whooping-cough. This appears to indicate that the tracheobronchial glands may be enlarged during the course of the illness" (Dawson Williams).

Pathology.—As the disease is so very seldom fatal, opportunities for the study of its pathology are correspondingly rare. In Mayer's case, referred to above, the red blood cells were pale, and showed a deficiency of hemoglobin; the proportion of red to white cells was normal, but the eosinophiles were increased both in size and number. In addition to what is said above under Etiology and Symptoms, we add the following from the article on "Glandular Fever," by Dawson Williams, in the "Twentieth Century Practice of Medicine."

"Cantlie became familiar in Hong-Kong in 1891, and therefore before the outbreak of plague (which occurred in 1894), with an idiopathic glandular enlargement occurring in children in an epidemic form. The enlargement, he states, involved usually only one gland in the neck over the sternomastoid muscle, but at its anterior border. Apparently, therefore, the adenitis affected the superficial and not the deep cervical lymphatics, which are those usually affected in glandular fever. He mentions the occurrence of these cases in the course of a discussion of *pestis minor*, without, however, suggesting that they were examples of mild plague. It must be admitted that glandular fever does in the nature of its local lesion present a certain resemblance to the mildest form of bubonic plague (*pestis minor*). It is a curious fact, taken in conjunction with the extension of bubonic plague in the East since 1894, that it has been recognized in the far East for some years that a disorder characterized by enlargement of the lymphatic glands, usually those in the inguinal region, might occur in epidemic form both on board ship and in regiments ashore. Although it has only recently been described (by Godding), many medical officers, both naval and military, appear to have been acquainted with the disorder under the name 'non-venereal bubo.' The glands usually affected are the inguinal, and Skinner has suggested that as the 'non-venereal bubos' in the cases he observed invariably occurred in the inguinal glands, and as the patients always had irregular action of the bowels, sometimes dysentery, and at other times apparently constipation, the enlargement of the inguinal glands may be due to secondary infection from the mesenteric lymph glands. The analogy between this theory of non-venereal bubo and that advanced by von Starck for glandular fever will be observed."

Diagnosis.—This is to be made from the symptoms, particularly the cervical adenitis; the diseases to be excluded are tuberculous adenitis, pharyngitis, tonsillitis, mumps, influenza, lymphatic leukemia, and (in severe cases) typhoid fever.

Prognosis is good except when the case is complicated by nephritis; in the Ohio epidemic referred to above there were no recurrences or sequelæ, and only one patient died, and she was a delicate child who had just had scarlet fever.

"The beginning of convalescence is in many, perhaps the majority, of the severer cases marked by the passage of thin greenish stools containing much mucus" (Dawson Williams).

Treatment is almost entirely symptomatic. Isolation is necessary, in order to prevent the spread of the disease. Rest in bed should be insisted on, at any rate during the period of fever; and the pain may be relieved, by hot or cold applications. Iron, cod-liver oil, light but nutritious food, and general hygienic surroundings are all indicated. Calomel has been recommended, but it has also been condemned. A mild fever mixture, which is sedative and diaphoretic, may be used, such as:

℞ Spts. ætheris nitrosi . . . . . ʒij.
Tinct. opii camphoratæ . . . . . ʒss.
Vin. ipecac . . . . . ʒss.
Liq. ammon. acetat . . . . . q.s. ad ʒiij. M.
Sig.—One teaspoonful q.3.h., for a child three years old.

Applications of belladonna are serviceable for the adenitis, and sodium salicylate should be given in the early stage of the disease when the fever is high and the pain severe.

R. J. E. Scott.

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Glaser, Johann Heinrich.—Born in Basel, Switzerland, October 6, 1629. He received his degree in medicine from the University in Basel in 1661, later studying in Heidelberg and Paris. In 1667 he was appointed professor of anatomy and botany in the University in Basel. He died in that city on February 5, 1675. Glaser was one of the noted surgeons and anatomists of his day, whose name has been preserved through his discovery of the petrotympanic fissure, found in the temporal bone, which is called the Glaserian fissure. The following are some of his contributions to medical literature: "Dissertatio de rheumatismo," 1661; "Theses opticæ," 1664; "Casus medicus de mensium suppressione, eorumque per aures excretione, ut et febre tertianâ curatâ," 1673; "Tractatus de cerebro," 1680. E.L.J.

Glauber, Johann Rudolf.—Born at Carlstadt, Germany, in 1603. At the age of twenty-one, while visiting Vienna, he obtained relief from a troublesome stomach complaint by drinking the water of a certain spring situated near Neustadt, about thirty miles to

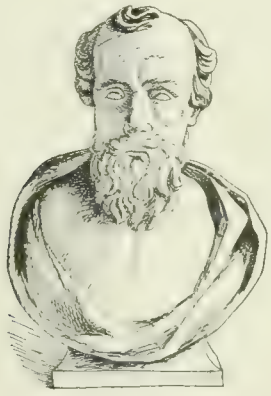


Fig. 2803.—Johann Rudolf Glauber.

the south of the capital. This experience led to his making some experiments for the purpose of ascertaining what was the essential chemical in those waters to which he owed the restoration of his health. The result of these experiments was the discovery of sulphate of soda, to which he gave the name of "Sal admirabile," but which all subsequent generations have known as Glauber's salts. (Wootton's Chron. of Pharm.) A. H. B.

Glaucoma.—The name of this affection of the eye has been bestowed upon it on account of a greenish appearance (γλαυκός) of the pupil, which, although present only in rare cases, may be observed as one of its symptoms. This name is a misnomer. It is, however, generally adhered to. More recent names, which were adapted to special theories regarding the character of the affection—as, for instance, ophthalmia arthritica, choroiditis serosa, etc.—have never been universally adopted.

Pathology.—The chief characteristics of glaucoma are a slowly or rapidly progressing diminution of the acuity of vision, combined with an occasional or continued increase of the intraocular pressure, and an excavation of the optic-nerve papilla. Around these chief symptoms and conditions we find grouped a number of other symptoms which characterize the different varieties of the disease. These varieties are known as *glaucoma simplex acutum, glaucoma simplex chronicum, glaucoma inflammatorium acutum, glaucoma inflammatorium chronicum.* When any one of these forms of glaucoma occurs in an eye which has not previously been affected in a manner such as to cause the development of glaucoma, we speak of the glaucoma as being *primary;* when, on the other hand, a previously diseased eye is, in consequence of this former disease, attacked by glaucoma, we call it a *secondary* glaucoma. We can furthermore, as a rule, recognize three stages in the development of all forms of glaucoma, the first of which is called the *prodromal* stage, the second that of *glaucoma evolutum,* and the last that of *glaucoma absolutum.*

What are usually described as the *prodromes* of glaucoma are observed in a large majority of the cases, and are in reality a series of slight attacks of acute, glaucoma. This prodromal stage may last for many months, or even for years, until the attacks and their consequences become more serious. The prodromal attacks are not equal either in duration or in degree; yet they are not serious enough, as a rule, to cause cupping of the optic disc, not to reduce the visual acuity lastingly. On the other hand, their early recognition is of grave importance to the patient, as the disease in these early stages is more tractable than later on. The symptoms which characterize this prodromal stage are the following: There is an appearance of a mist before the eye or eyes, and this mistiness may change in density. Rainbow colors are seen, especially in the shape of a ring around a candle flame. These rainbow-color rings do not touch the flame, but are separated from it by a dark space. The range of accommodation is reduced, and the eye appears prematurely presbyopic. This symptom is probably due to the hyperemia of the ciliary body. In some cases the eye becomes myopic, which fact can be explained only by the assumption that the crystalline lens *in toto* is pressed forward toward the cornea, and that, in spite of the fact that in this manner the zonule of Zinn is

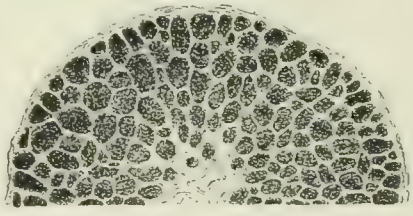


Fig. 2804.—Section of the Optic Nerve in a Hypermetropic Eye, just behind the lamina cribrosa.

stretched, and that an applanation of the lens is taking place. There is pain, which may be slight or even excruciating, and which is located in and around the eye, and in the forehead, the eyebrows, the cheek bones, the nose, and the temple. There is an increase of the intraocular pressure, which will manifest itself by an increase in the degree of tension of the eyeball; this increased tension varying from a barely perceptible to a stony hardness. The intraocular pressure is tested by directing the patient to look downward, then gently laying the tips of the forefingers upon the upper lid, and alternately press-

ing them upon the eyeball, as we do when we are searching for fluctuation elsewhere. By comparing the amount of impression we are able to make on a diseased eyeball with that which we can produce on its healthy fellow, or on the healthy eye of a third person, we can form an estimate of the increase of intraocular tension in the given case. According to the degree of hardness, we speak of it as +T. (tension) $+T_1$, $+T_2$, and $+T_3$. Several instruments (tonometers) have been invented to give an exact measurement, but until the tonometer of Schiötz was produced none seemed to be of real value. The Schiötz tonometer comes much nearer the

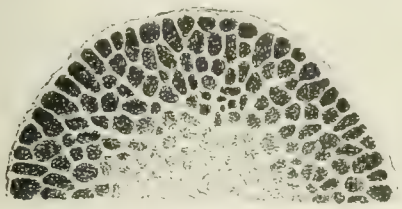


Fig. 2805. Section of the Optic Nerve in a Hypermetropic Eye, near the anterior surface of the lamina cribrosa.

ideal and at the present time is used everywhere. Thus the vague measuring of tension by the finger has given way to a scientific measurement which is very nearly exact.

The prodromal stage passes over into that of the *glaucoma evolutum* as soon as the visual acuity is lastingly reduced.

Glaucoma simplex acutum is, if ever, very rarely observed. It would seem to have existed in a few cases in which sight was lost within a few hours without any inflammatory symptoms, and with barely increased pressure.

Glaucoma simplex chronicum is characterized by the fact that externally the eye shows no marked signs of disease. The cornea, anterior chamber, iris, and pupil appear normal. The main symptoms are: The loss of vision, the excavation of the optic papilla, and the increase of the intraocular pressure. The latter symptom may, however, be imperceptible, or it may be present only at times.

An increase of the intraocular pressure is generally accepted to be the cause of the glaucomatous excavation of the optic papilla. The normal optic papilla has a more or less centrally located depression (physiological excavation) which may, in rare cases,

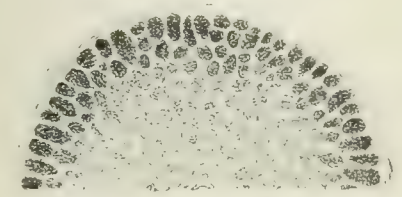


Fig. 2806. Section of the Optic Nerve in a Hypermetropic Eye, at the anterior surface of the lamina cribrosa.

reach so far toward the periphery of the optic papilla that at first sight it will strike the observer as a glaucomatous excavation. I have seen several cases in which the absence of all other symptoms alone convinced me of the fact that I was not dealing with a chronic glaucoma. Such a physiological excavation may have a sloping or a sharp edge, and may appear quite deep, yet it can never reach farther back than the anterior surface of the normal lamina cribrosa. In our judgment of the width as well as of the depth of such a physiological excavation we must take into consideration the fact that the optic nerve fibers, after they have passed through the lamina cribrosa, lose their marrow, become non-medullated, and are then diaphanous. Thus, a physiological excavation of the optic papilla is likely to appear much larger than it actually is. The illustrations, Figs. 2804, 2805, 2806, and 2807, will give a more palpable illustration of this fact. They are specimens of a very

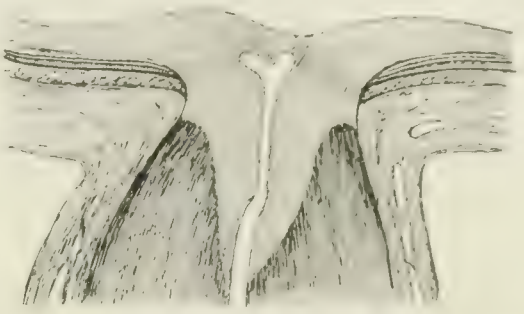


Fig. 2807. Longitudinal Section of the Optic Nerve in a Hypermetropic Eye.

short (hypermetropic) eye. The eye from which they were taken probably showed during life an apparently very large physiological excavation, while the central (actual) excavation, caused by the manner in which the nerve fibers pass over into the retina, is only very slight. The condition illustrated by these drawings is chiefly found in hypermetropic eyes, while in myopic eyes the double-contoured nerve fibers reach farther forward and end in a straight, or even slightly convex, line.

If we now compare with this physiological excavation the typical glaucomatous excavation (see Fig. 2808), we find that here we have to deal with an actual and deep hollowing out of the optic papilla.

We furthermore see, in this figure, that the actual excavation has for its floor a thin layer of atrophic nerve fibers and the compressed lamina cribrosa. The nerve-fiber layer and the lamina cribrosa are together pressed out of the sclerotic, and behind it into the trunk of the optic nerve. The walls of the excavation are also lined with a very thin layer of

Fig. 2808. Glaucomatous Excavation.

atrophic nerve fibers. These fibers follow very closely in their course the indentations and projections of the surrounding scleral tissue, and finally pass over into the atrophied nerve-fiber layer of the retina.

From the foregoing, we understand that the physiological excavation in the normal eye may appear as having a sharp edge, but usually it has none, and can-

not, for obvious reasons, reach to the periphery of the optic papilla; that the typical glaucomatous excavation, however, has always a sharp edge, and can reach to the very periphery of the optic papilla (when all nerve fibers are destroyed), and always comes very close to it. Moreover, in the typical glaucomatous excavation, the lamina cribrosa is pressed backward and out of its normal position. It can, therefore, not well be confounded with a simple atrophic excavation, since this is always very shallow, and the lamina cribrosa is found in its normal position and of normal appearance.

By the aid of these anatomical facts we shall now easily understand the ophthalmoscopic picture of a glaucomatous excavation (see Fig. 2809).

The most striking phenomena of a glaucomatous excavation pertain to the retinal blood-vessels. Just before reaching the optic-nerve papilla these

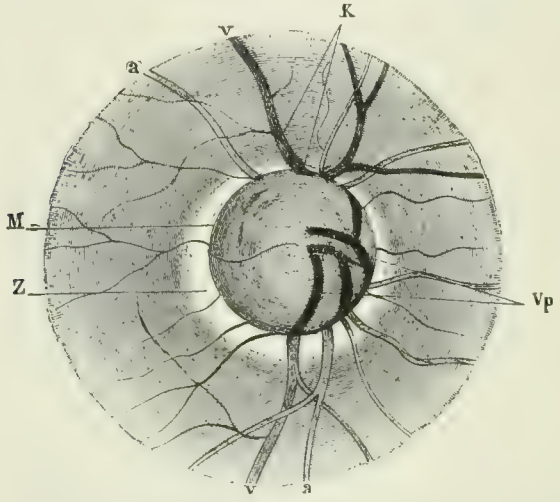


Fig. 2809.—Glaucomatous Excavation as Seen with the Ophthalmoscope. (From Edward von Jaeger.) *a*, *a*, Arteries; *v*, *v*, veins; *K*, points, on the border of the papilla, where the vessels make a sharp bend; *Vp*, portions of blood-vessels lying in the excavation; *M*, border of the excavation; *Z*, surrounding yellow zone.

blood-vessels are seen to pass over a yellowish ring, which corresponds neither to the normal scleral nor to the normal connective-tissue ring as seen around the normal optic papilla. On the inner margin of this yellow ring the blood-vessels are seen to bend inward, then they disappear partially or altogether, and reappear dimly in the depth of the excavation, but in a parallactic displacement. If the excavation is very deep, it may be impossible to see those vessels which are located in the floor, while those which occupy the retinal portion are distinct, and *vice versa*. The depth of the excavation may thus be approximately measured by means of the difference between the glasses necessary to see the two portions distinctly.

The optic nerve forming the bottom of the excavation appears punctated. It has usually a white appearance in the center, where it is directly illuminated, while the parts which are only indirectly illuminated appear bluish or greenish. By moving the mirror slightly the view may be changed in such a manner as to make a formerly greenish part appear whiter. The punctation is probably produced by the fact that the meshes of the anterior surface of the lamina cribrosa are visible on account of the atrophy of the nerve fibers.

The yellowish ring around the optic papilla, or at least what is left of it, is caused by an atrophic condition of the choroid, which is undoubtedly due to the stretching of this membrane during the development of the excavation, and is not due, as some authors maintain, to a chronic choroiditis.

A further vascular symptom is the spontaneous pulsation of the retinal arteries. This is but rarely seen in recent cases. It can easily be produced by pressure on the eyeballs.

The gradual loss of sight (central visual acuity and visual field) is in a general way in proportion to the size and extent of the excavation of the optic papilla and the consequent atrophy of the optic nerve fibers. Nevertheless, a number of cases have been observed and reported in which an apparently large and deep excavation had not yet become associated with a great loss of vision. In some cases the central or paracentral vision will be destroyed before the periphery seems to be materially altered, and in other cases the loss of vision at first affects the peripheral vision alone. The contraction of the visual field begins frequently on the nasal side, and gradually extends upward and downward, so that in some cases at a certain stage a perfect hemianopsia has been observed. Gradually the visual field grows smaller and smaller. It often has the shape of a horizontal ellipse with the point of fixation lying in the nasal focal point. This form of contraction of the visual field is pre-eminently found in glaucoma, while an actually concentrical limitation of the visual field is usually due to diseases of the optic nerve alone, or to retinitis pigmentosa with subsequent atrophy of the optic nerve.

All these symptoms are accompanied by a gradual diminution of the light sense. The color sense is usually well preserved, even when the visual field is reduced to almost nothing.

The loss of vision and the reduction of the light sense are the symptoms of glaucoma simplex which usually bring the patient to seek relief. Generally one eye is then already found to be badly affected, while the disease is beginning in the second eye.

Glaucoma Inflammatorium Acutum.—The attack of acute inflammatory glaucoma comes on suddenly, and probably more frequently during the night than in the daytime. The pain, which is the most prominent symptom of this form of glaucoma, is often fairly excruciating. It is seated in the eyeball, the eyebrow, the forehead, and temple, and it may extend even to the occipital region. It may be combined, furthermore, with nausea and vomiting. There is usually a considerable secretion of tears and of watery fluid from the nose, and photophobia is likely to be present. These symtoms are, moreover, accompanied by some edema of the eyelids, and especially of the upper one. Ayres has seen a case which was ushered in by intense chemosis. When the lids are separated, the conjunctival blood-vessels are found to be considerably injected, and the bulbar conjunctiva to be slightly chemotic. The episcleral vessels around the cornea, too, are hyperemic, and form a reddish-blue ring around the corneo-scleral margin. The anterior ciliary veins are distended and tortuous.

The cornea has a dead appearance, like glass which has been breathed upon. Under oblique illumination its surface appears irregular, as if pricked with a needle, and there may be slight deposits of fibrin on Descemet's membrane. If the cornea is touched with the end of a probe, a feather, or a thin roll of tissue paper, it is found to be almost anesthetic, and the reflex contraction of the orbicularis muscle of the eyelids follows the insult long after it does so in a healthy eye. This anesthesia may be noticeable over the whole area of the cornea or only in portions of it. By palpation the eye is found to be hard. This sudden increase of the intraocular pressure is the cause of the dimness as well as of the anesthesia of the cornea.

The anterior chamber is shallow, the iris and crystalline lens being pressed forward toward the cornea. The pupil is wide, and reacts but very

slightly under the stimulus of light. There may be some posterior synechiæ.

When the attempt is made to get an ophthalmoscopic view of the interior of the eyeball, it is often barely possible to see a reddish reflex, but no details of the fundus. This is due as well to the dimness of the cornea as to a diffuse opacity of the vitreous body.

Sight is considerably reduced, and it may be diminished to the bare preception of light. This symptom is most probably due to the pressure exerted upon the optic nerve fibers, the retina, and the retinal blood-vessels, and to the resulting paralysis of the nervous elements and ischemia of the retina. That this is the correct explanation of the symptoms seems to be proven by the pulsation of the retinal arteries, the systole of the heart alone being able to overcome the intraocular pressure to some extent, and by the fact that a release of the pressure by operation will restore sight. The dimness of the cornea and the vitreous body, moreover, help to reduce the vision.

The attack of acute inflammatory glaucoma may last from a few hours to several weeks, and sight may again considerably improve as the attack passes over. Nevertheless, the eye, although it may look so, is no longer in the same condition as before the attack, and every new attack will leave it in a worse state. Repetitions of the attack are the rule. In the intervals between the attacks the anterior chamber remains usually shallow, the movements of the iris are restricted, and the tension remains somewhat increased. In other cases the acute stage passes directly over into the chronic one. When all these symptoms are less marked, the affection is called *glaucoma subacutum*.

There is, furthermore, a limited number of cases of acute glaucoma on record in which sight was absolutely destroyed during the first attack, and in the course of a few hours. These cases have been given the name of *glaucoma fulminans* (von Graefe).

Glaucoma Inflammatorium Chronicum.—In the chronic inflammatory form, which may follow an acute attack or begin with a chronic character, all of the glaucomatous symptoms are slowly developed, and the external inflammatory signs are less marked than in the acute form. The injection of the conjunctiva is there, but there is no edema of this membrane, nor of the eyelids. The episcleral blood-vessels, and especially the anterior ciliary veins, are plainly visible and tortuous (see Fig. 2810). There

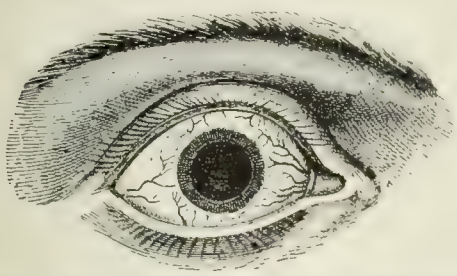


Fig. 2810.—Chronic Inflammatory Glaucoma. (After Schmidt.)

is a marked injection of the deeper-seated blood-vessels around the corneoscleral margin, and in the later stages the sclerotic tissue has a peculiar leaden appearance. The cornea may be perfectly clear, or it is slightly hazy, and it often shows minute superficial or even deeper points of ulceration. The anterior chamber is shallow and becomes more and more so as the disease advances; and the pupil, which is at first of medium size and acting sluggishly, soon undergoes an increasing degree of dilatation and becomes immovable. The iris tissue, at first swollen and discolored, will be found, at a later date, attenuated, and undergoes a slow process of atrophy. The intraocular pressure is increased above the normal, and there is a gradually increasing excavation of the optic papilla with a consequent atrophy of the optic nerve fibers.

The patients suffer at times from considerable pain and neuralgia, especially at night. The visual acuity, the visual field, and the light sense are gradually more and more reduced. This is the more noticeable after each exacerbation of the process.

The chronic inflammatory glaucoma seems to be the most frequent form in which this disease is observed. We must state here that the acute inflammatory, as well as the chronic inflammatory, variety may be preceded by a simple chronic glaucoma.

When the sight, through the effects produced by the glaucoma in one of its different forms, has been perfectly abolished, or at least to such a degree that merely the perception of light is retained, we speak of the condition as *glaucoma absolutum*. The progress of the disease, however, does not end here, and a further glaucomatous degeneration of the eyeball takes place. In some cases the eye is only at times painful and shows but slight external alterations, and the media may remain for a long period in such a condition that an ophthalmoscopic examination can easily be made. In most cases, however, the increasing malnutrition leads to the formation of glaucomatous cataract. The anterior chamber becomes so shallow that the anterior lens capsule almost touches the posterior surface of the cornea, or actually does so. The eye remains painful, and the pain is at times very considerably exaggerated. Gradually vesicles may be formed on the cornea, ulceration of the cornea and the formation of scleral or corneal staphylomata may take place. The ulceration may lead to perforation and subsequent shrinking of the eyeball. All these symptoms may be accompanied by very annoying photopsiæ.

In the foregoing we have considered what is designated as primary glacuoma. We come now to the forms of secondary glaucoma.

Secondary glaucoma may appear in the shape of a simple or inflammatory glaucoma. It has been observed to follow various diseases of the eyeball. It may follow a diffuse or sclerosing keratitis, vesicular (bullous) keratitis, or that form which is known as ribbon-shaped keratitis; yet it is more frequently observed in cases of anterior synechia, with or without leucoma of the cornea.

So-called serous iritis and iridochoroiditis are apt to cause glaucomatous symptoms. Glaucoma may furthermore follow a plastic iritis when it has led to the formation of posterior synechiæ, and especially when a total circular synechia has been formed, whether this has led to the seclusion of the pupil alone, or to seclusion combined with occlusion of the pupil. But an occlusion of the pupil alone (which can, for instance, follow an operation for cataract extraction) may also be sufficient cause for the production of glaucoma.

Dislocation of the crystalline lens, or a too rapid swelling of the lens substance after the operation of discission or after an injury to the lens capsule, may lead to glaucoma. This is one of the bad results which often followed the old method of couching cataractous lenses.

Serous choroiditis, although leading more frequently to detachment of the retina, may give rise to glaucoma.

The most important one among the diseases of the retina which may be followed by glaucoma is the hemorrhagic retinitis (*glaucoma hemorrhagicum*). In fact, hemorrhages into the retina from any cause may lead to hemorrhagic glaucoma. The pathological substrata are some form of disease of the blood-vessel walls, an inability of the filtration channels to

carry off the corpuscular elements of the blood, and a consequent blocking up of these channels. Glaucoma has been furthermore observed in cases of pigmentary retinitis and of atrophy of the optic nerve. In these cases the occurrence of glaucoma was, however, probably a coincidence only, and it would seem to have been a primary glaucoma, not a secondary one.

Collins, Keyser, Buller, Knapp, and the writer have had occasion to see glaucoma follow cataract extractions and needle operations. In these cases the lens capsule or the vitreous body, with or without some part of the iris, was found to have blocked the filtration angle.

Secondary glaucoma is apt, furthermore, to occur in eyes suffering from staphyloma, and the increase of pressure then helps to the further increase of the staphyloma.

All intraocular tumors are likely to cause a glaucomatous condition of the eye during their growth.

Hydrophthalmus congenitus (cornea globosa; buphthalmus; keratoglobus) must probably be regarded as intrauterine glaucoma.

Ayres saw a case of glaucoma caused by a very large nasal polypus. A cure was effected by the removal of this tumor.

The instillation of any and all mydriatics, even of one as weak as euphthalmin, may, under favorable circumstances, bring about an attack of acute glaucoma.

Diagnosis.—The differential diagnosis between glaucoma simplex chronicum and amblyopia caused by a simple atrophy of the optic nerve may be sometimes rather difficult, especially since there are cases of simple glaucoma in which there is no *appreciable* increase of the intraocular tension, and they may come under observation when as yet there is only a partial excavation of the optic papilla. This difficulty is to be met only by repeated careful examinations, until one of the necessary symptoms is marked enough to make the diagnosis secure. In this connection I may mention that the yellowish halo around the optic papilla which is characteristic of glaucoma, though little marked, seems to be but seldom wanting, and may therefore help in making the diagnosis. Furthermore, a simple atrophy of the optic nerve may at a comparatively early stage lead to diminution of the color sense, while glaucoma does not seem to interfere often with the color perception.

The diagnosis of an acute primary inflammatory glaucoma may appear plain from the condition of the eye when it comes under observation; yet the same general condition might also be a secondary one and due to an intraocular tumor. Here the position of the defect in the visual field, the usual absence of the perception of rainbow rings, and the gradual and continuous loss of vision which is likely to have preceded the glaucomatous condition under consideration, may help to the diagnosis of an intraocular tumor, even if it cannot be otherwise demonstrated. To distinguish between a hemorrhagic and a primary acute glaucoma will hardly be possible, except in cases in which the retinal hemorrhages had obscured vision very materially, or in which the observer has had occasion to see the occurrence of such hemorrhages previous to the glaucomatous attack. The acute glaucoma might, furthermore, be confounded with serous iritis. Yet, the deposits on Descemet's membrane which are so marked in this affection, the depth of the anterior chamber, and the low degree of injection of the visible external blood-vessels (there may be none at all) will usually make it possible to exclude a primary glaucoma in such cases.

Glaucomatous, as well as any other complicated, cataract may, of course, by a careless observer, be taken for an uncomplicated cataract.

The primary chronic inflammatory glaucoma cannot well be confounded with any other eye affection.

Glaucoma is observed in about one per cent. of all eye patients. It seems to be a little more prevalent among females than among males. It has been seen to occur in children as well as in old age. Yet the majority of the cases are observed after the fiftieth year of life has been reached, and it is very seldom seen before the twentieth. Although glaucoma may at first attack only one eye, it is the rule that it will sooner or later attack the fellow-eye. In this connection we may state that the attack in the second eye seems to be apt to make its appearance soon after the first one is operated upon.

In the relative frequency of their occurrence the chronic inflammatory glaucoma takes the first, the chronic simple glaucoma the second, the acute inflammatory glaucoma the third, and the (doubtful) acute simple glaucoma the last place. The disease is almost confined to eyes afflicted with hyperopia or hypermetropic astigmatism, although it is found also occasionally to appear in myopic eyes, especially the chronic simple form. Some authors maintain that there is an inherited tendency to glaucoma in some families.

Where there is a tendency to glaucoma, an attack may be brought on by an extraordinary straining of the eyes, by mental disturbances, by excesses of various kinds, by various diseases, by the stopping of habitual secretions, especially of the menstrual flow in the climacteric period in females, and, as stated, by the instillation of a mydriatic into the conjunctival sac.

Before considering the nature of this disease we will next see what data the anatomical examination of eyes afflicted with glaucoma gives us to build our theories upon.

Pathological Anatomy.—The most interesting part of a glaucomatous eye has been for a long time the optic-nerve papilla, with its excavation. In a case which is not very far advanced, we find a comparatively shallow excavation, which is deepest usually in the center, sometimes at one side (especially the temporal one). The bottom of this excavation lies behind the level of the choroid, and consists of a thin layer of nerve fibers. Nerve fibers are, furthermore, seen to line the walls of the excavation, and to join the retina at a more or less acute angle. The retinal blood-vessels lie within this nerve-fiber layer, and come, according to the stage of the disease, more or less close to the edge of the excavation. The fibers of the lamina cribrosa appear pressed closely together, so as to render this membrane thinner than in the normal eye, and the whole lamina is bulged outward. Its choroidal portion is no longer in distinct connection with the choroid. The small blood-vessels found in the normal eye in this region are reduced in numbers or wanting altogether, and the nerve fibers are atrophied. The retinal veins are usually hyperemic. All these conditions are considerably exaggerated in an advanced case like the one from which Fig. 2808 was taken, yet I have never seen a glaucomatous excavation which had not, though ever so thin, a lining layer of nerve fibers.

The portions of the choroid and the retina which surround the excavation are drawn to some extent down into it and toward its axis, and the choroid is, even in the more recent cases, very thin and atrophic. It lacks blood-vessels, especially capillaries, its pigment cells have, in a certain measure, or altogether, disappeared, and the pigment molecules are found lying in the adjoining tissue of the sclerotic. This condition is undoubtedly the anatomical explanation of the glaucomatous halo. In some cases small foci of infiltration are found in this portion of the choroid.

The choroid in general shows an anemic condition of the capillary layer; while the venæ vorticosæ are

usually choked with blood. Atrophic patches are sometimes found in its periphery.

The retinal nerve-fiber layer in very advanced cases is atrophied, and the blood-vessels of this membrane are partially or altogether obliterated.

In more recent time (Knies) the interest of the examination has been centered especially on the condition of the iris angle. We find here, although not at all invariably, an adhesion between the periphery of the iris and the posterior surface of the cornea. Thus the spaces, which in the normal human eye lie between the fibers of the ligamentum pectinatum and correspond with the canal of Fontana, are partially or totally obliterated. In recent cases the tissue surrounding Leber's venous plexus (corneoscleral tissue) is infiltrated with round cells, and the periphery of the iris, being pressed forward, comes in contact with Descemet's membrane, the endothelial coat of which begins to proliferate. In this way a small amount of new connective tissue is formed between Descemet's membrane and the periphery of the iris, and this glues the two together, thus causing the obliteration of the spaces of Fontana (see Fig. 2811).

It is doubtful whether this agglutination of the iris to Descemet's membrane is due alone to the increased intraocular pressure, or to the direct pressure (Weber, Brailey) of the swollen and hyperemic ciliary bodies. According to Brailey, the blood-vessels of the ciliary region are found to be considerably dilated, and their walls are reduced in thickness. Later on, the ciliary bodies and muscles are found to be thin and atrophic, and the smaller blood-vessels are obliterated. Leber's plexus is found patent or closed. In other cases the iris angle is found to be quite large and not blocked by iris tissue. In such cases the filtration channels are filled with cell detritus and fibrin, and thus a stoppage results.

Fig. 2811.—Adhesion of Periphery of the Iris to Descemet's Membrane, causing Dilatation and Immobility of the Pupil, and Obliteration of the Iris Angle.

Cusco stated that the sclerotic coat is always thicker in glaucomatous eyes, and especially near the entrance of the optic nerve. Weichselbaum and others found the episcleral veins filled with blood, and dilated and surrounded by foci of round cells. In some cases a proliferation of the endothelial coat of the venæ verticosæ has been observed.

Ulrich examined pieces of the iris which he had excised from glaucomatous eyes when making an iridectomy. He found the tissue of the iris atrophied and thin, and lacking cellular elements. The blood-vessels were partially dilated, and the thickness of their walls was considerably reduced—some of them (especially of the smaller ones) were totally obliterated.

In some cases the vitreous body has been found detached. The cornea is usually edematous.

It will be seen from the foregoing remarks that our knowledge of the pathological anatomy of glaucoma is as yet very meager. This is the more astonishing, as a great many able workers have devoted considerable study to this interesting, and as yet mysterious, disease. Glaucoma, or at least a similar condition, has been experimentally produced in animals by ligating the venæ vorticosæ, by burning the corneoscleral margin (Schoeler), and by injecting oil into the anterior chamber (Weber).

It is therefore evident that even to this day it has been impossible to find a common cause for all the different forms of affections which produce the increase of intraocular pressure, as well as the gradual destruction of vision, combined with an excavation of the optic nerve—in brief, for the disease which we call glaucoma. Consequently, it is not to be wondered at that the number of theories constructed for the explanation of the nature and seat of glaucoma is legion. These theories may be classed under three heads: Those which make the increase of the intraocular pressure the main feature; the theories which deal with the disease as originally due to a strange affection of the optic nerve; and, finally, those which seek the cause in an inflammation of the choroid. To these must be added the newest theory of Stransky who considers an indurating inflammation of the sclerotic to be the cause particularly of chronic simple glaucoma. The failure of iridectomy in this form of glaucoma he considers a strong proof of his theory.

Theories Put Forward in Explanation of the Disease.—The theories making the increased intraocular pressure the main feature attribute it to a hypersecretion into the vitreous body, consequent upon an active but somewhat atypical inflammatory process in the choroid; or they consider it due to an irritation of the secretory nerves; or the increase in pressure is thought to be the result of reduced facilities of excretion from the eyeball, or of stasis of the venous blood (passive hypersecretion, Mauthner).

Von Graefe thought that glaucoma was a choroiditis or an iridochoroiditis, with diffuse imbibition of the vitreous body—processes which would lead to an increase in volume of the vitreous body, and consequently to increased intraocular pressure. Later on, he thought this choroiditis to be due to an irritation of the secretory nerves. Arlt and Sattler adhere to the former theory. The latter found inflammatory changes in the choroid, but his description of these changes is such that it seems hardly possible to attribute a disease of the character of glaucoma to so slight a cause. If this explanation were correct, why, it may be asked, is not a glaucoma produced in every case, or at least in the majority of cases, by an exudative choroiditis?

The neurotic theory has been put forth by Donders. He says that in glaucoma chronicum simplex we have no signs of an inflammatory character, and, furthermore, the increase of pressure has always preceded the inflammatory symptoms where they exist. The cause of the increased pressure must, therefore, lie in the irritation of secretory nerves. Von Graefe, as stated before, partially adopted this theory; but he characterized even the glaucoma chronicum simplex as an inflammatory condition. Schnabel, who also supports the neurotic theory, refuses to acknowledge the inflammatory character of any form of glaucoma. He claims that the glaucomatous ophthalmia is simply a neuralgia of the sensory nerves, while the increased pressure is due to a neuralgia of the secretory nerves of the eye. Glaucomatous ophthalmia, then, and anomaly of pressure, spring from the same root.

The cause of the secretory neurosis is found in the atrophy of the ciliary processes and the consequent enlargement of the diameter of the circle formed by these processes, which enlargement causes an increased tension of the suspensory ligament of the crystalline lens.

The intraocular irritation of the secretory nerves lies, therefore, in the anterior part of the eyeball, the iris, and the ciliary body (Donders, Schnabel, Roeder), and is a reflex neurosis.

It might, however, with the same right be claimed that it is an extraocular affection which brings about such a reflex neurosis, and thus Hutchinson and Schmidt-Rimpler have considered a neuralgia of the trigeminus nerve as the cause of glaucoma. Mooren finds the cause in affections of the brain or spinal medulla.

Weill has formulated and elaborated a theory in which he tries to prove that all the symptoms of glaucoma are due to irritation of the sympathetic nerve.

The most plausible theories yet advanced are those which refer the cause of glaucoma to mechanical obstructions to the drainage of the fluids from the eyeball, either by obliteration of the lymphatic channels in the iris angle and, perhaps, in the optic nerve, or by obstruction of the reflux of the venous blood from the eyeball. Such obstructions must undoubtedly cause an increase of intraocular pressure, if at the same time the afflux remains the same.

The present status of our knowledge of the course of the nutritive fluids of the eyeball is chiefly due to the labors of Knies. He found that the fluids are secreted by the choroid, ciliary body, and iris. The fluids coming from the choriocapillary layer take their course through the retina into the vitreous body, then forward toward the crystalline lens. While a portion of these fluids now penetrates the equatorial portion of the lens, the larger quantity goes through the suspensory ligament and around and through (Ulrich) the iris into the anterior chamber. The aqueous humor is secreted by the anterior portion of the ciliary body and the iris. In the normal eye no fluid is excreted through the cornea (Leber), or, if any is excreted, the quantity is very small. The way by which the largest portion of the aqueous humor leaves the eyeball is through the iris angle; here it goes partially into Leber's venous plexus and partially into the lymph canals of the conjunctival and episcleral tissue, and of Tenon's space; and, perhaps, a part leaves by way of the iris itself.

It seems, therefore, evident that an obstruction of the excretory canals will cause glaucoma. Such an obstruction may be due to an inflammation in the iris angle, which, as we saw, brings about an actual adhesion between Descemet's membrane and the periphery of the iris, with or without obliteration of Leber's venous plexus (Knies); or it may be due to entanglement of cell detritus in the meshes of the ligamentum pectinatum; or, finally, it may be due simply to the swelling of the ciliary processes, which will press the periphery of the iris against the corneoscleral tissue (Priestly-Smith, Brailey, Weber). According to Priestley-Smith the size of the lens is, so to speak, too large for the eye in most cases. Thus accommodative strain may crowd the iris periphery against the cornea. Furthermore, the obstruction may be caused by the atrophy of the iris tissue and the consequent obliteration of the channel by which, in the normal eye, fluids pass directly through the iris (Ulrich). Some authors speak of an obliteration of the lymph canals near and in the optic-nerve entrance as the partial cause of glaucoma. Gifford has shown that there is a current backward in the lymph spaces accompanying the central retinal vessels.

The obstruction of the reflux of the venous blood from the eyeball may be due to an increased rigidity of the sclerotic (Stellwag, Arlt); to inflammation and consequent increased thickness of the sclerotic (Cusco); to fatty degeneration of the sclerotic (Coccius), all of which pathological changes will tend to compress the venous blood-vessels. Magni finds that the ciliary nerves are atrophic in cases of glaucoma. This atrophy of the ciliary nerves causes shrinking of the vitreous body and sclerotic, and stasis in the venous blood-vessels. This stasis, according to others, may be due to an infiltration of the tissue surrounding the veins, or to a proliferation of their endothelial coat.

All of these theories take glaucoma to be a disease due to a reduction of the area of the channels of excretion, and they consider all other symptoms of the disease, including inflammatory attacks, anesthesia of the cornea, and excavation of the optic papilla, to be directly dependent on the increased intraocular pressure.

Most recently Schoen has advanced a new theory of glaucoma, which also refers the cause of the disease to mechanical conditions of the eyeball. Although it does not strictly belong among the "pressure theories," it may find its place here. He says that an overstrain of the accommodation is the etiological momentum in the development of all cases of primary glaucoma. This may act in two ways: by pulling the sheaths of the optic nerve forward (thus causing excavation), and by pressing the crystalline lens forward (thus producing glaucomatous increase of pressure). As long as all the fibers of the ciliary muscles act, glaucoma simplex will follow this overstrain. When the inner fibers of the ciliary muscles become insufficient as compared with the outer ones, the lens is pushed forward, and glaucoma, with increased pressure, is the result. The two modes can act combinedly in various ways. The pathological changes found in the ciliary body are due to subsequent inflammation.

The theories which consider glaucoma due to an affection of the optic nerve were inaugurated by Jaeger. He sees the direct cause of the disease in changes in the ring of blood-vessels which bring blood to the portion of the sclerotic surrounding the optic-nerve entrance, to the lamina cribrosa, and to the optic papilla (Haller's ring). He denies that the increased intraocular pressure is characteristic of the glaucomatous process, although it is an important symptom. Schnabel and Klein support this theory.

The theories which take glaucoma to be the result of a choroiditis, and assume that this choroiditis alone (without increase of pressure) would lead to the loss of function and excavation of the optic papilla, have found their most urgent advocate recently in Mauthner. He says that glaucoma is an inflammatory process in the system of the ciliary blood-vessels—a process which may concern the whole area of this system, or leave some portions of it free; an inflammatory process which (with the exception of the location of the glaucomatous halo) is distinct from others by the lack of formed elements in its products, and by the faculty of inducing a rapid atrophic process in the tissues involved. This inflammation is often combined with an increase of the intraocular pressure. This is less marked when the inflammation concerns only the area of the short posterior ciliary arteries that go to the choroid, but is hardly wanting whenever the area of the anterior ciliary arteries and long posterior ciliary arteries (ciliary body, iris, and cornea) is attacked; in this latter case the fluid secreted into the vitreous body is exuded from the inflamed ciliary body (Brailey). The increased intraocular pressure is not a constant symptom, and it is not the source of the functional trouble. This latter is caused by the fact that the inflammatory process of the choroid exerts its action upon the neighboring layer of the retina (the rods and cones) while the affection of the optic papilla, characteristic of glaucoma and due to the inflammation in the area of the arterial scleral ring, plays only a secondary or final rôle in the total ruin of vision.

When the glaucomatous inflammation suddenly attacks the area of the long posterior and anterior ciliary arteries (a kind of kerato-iridocyclitis), we have the acute inflammatory glaucoma. The disturbance of vision is only proportionate to the dimness of the media; the function of the retina does not suffer from the sudden increase of the intraocular pressure. In exceptional cases the uveitis, which is the glaucoma, will suddenly attack the *whole* area

of the ciliary blood-vessels; the attack, then, of course, includes the choroid. The function of the rods and cones may be thus suddenly (and usually forever) destroyed by the exudation; this is the case in glaucoma fulminans; or these organs may at least suffer considerably and lastingly; this is the case in glaucoma acutum inflammatorium.

Whenever the inflammatory process creeps slowly and in a chronic manner from in front backward, or *vice versa*, we have the glaucoma chronicum inflammatorium. In the former case the excavation will be developed at a late period only, while in the latter case the excavation will exist before any inflammatory changes appear in the anterior portion of the eyeball.

When the affection is a chronic choroiditis posterior, we have the glaucoma chronicum simplex; and the glaucoma acutum simplex is that rare form in which this posterior choroiditis appears acutely; a form of glaucoma, however, which is very soon followed by the anterior choroiditis in such a manner that the painless increase of intraocular pressure and blindness are soon succeeded by inflammatory changes in the anterior portion of the eyeball.

The writer may here state that it seems to him impossible to adopt such a theory, as the choroiditis on which it hinges does not seem to exist. Careful examinations of many glaucomatous eyeballs have not revealed the presence of inflammatory changes in the choroid which would be important enough to be taken as a cause of the series of symptoms constituting the disease which we call glaucoma. It seems to the writer that the theories which seek the cause of glaucoma in a mechanical obstruction of the outlets of blood and lymph fluids from the eyball are the most plausible ones, and there can, it seems, be no doubt but that a number of different influences may bring about such an obstruction. That the once increased pressure can easily cause an excavation of the optic papilla in hyperopic eyes, at least, seems to be plain from Figs. 2804–2807.

We may here again mention the theory which sees in an indurating scleritis the source of glaucoma.

In more recent years Richey and a number of followers have again brought forward an older theory, according to which glaucoma is said to be the result of uric-acid diathesis, and they seem to have strengthened their views by numerous observations of improvements and cures by careful treatment of the lithemia.

Prognosis.—The prognosis of glaucoma, unless its progress is interfered with by therapeutical or operative measures, is absolutely bad.

Treatment.—In the medical treatment of glaucoma an important step forward has been made since the myotics, and especially the sulphate of eserine (physostigmine, Laqueur) and the muriate of pilocarpine have been found to reduce the intraocular pressure. The value of these remedies in glaucoma is, however, a rather limited one. They do not and cannot cure glaucoma, but by their tension-diminishing influence they act beneficially during the prodromal stage, and they may well serve to stave off a threatening attack of glaucoma. By the forcible contraction of the sphincter pupillæ, induced by the action of these remedies, the periphery of the iris is, as long as this is yet possible, pulled away from the ligamentum pectinatum and thus its obstruction may be partially or even totally abolished for the time being. These remedies are, furthermore, of value before and after an operation for this disease. When instilled into the eye they generally also ease the pain of an inflammatory attack.

To this must be added the subconjunctival injection of sodium citrate (Fischer) which does not seem to be of much value. Furthermore, the ingestion of calcium chloride which has been advocated by Weekers and in the hands of the writer has, also, proved of some value.

A cure of glaucoma or, at least, an arrest of the process, is to be accomplished only by operative measures. Among these iridectomy (von Graefe) as yet holds the first place. Its value is greatest in the acute inflammatory and then in the chronic inflammatory forms, least in the chronic simple glaucoma. An early iridectomy in a case of acute inflammatory glaucoma is likely to bring vision again up to the normal. If performed at a later stage it may not be able to restore more than a part, or even nothing, of the lost vision. In the chronic inflammatory form the iridectomy usually restores a part of the lost vision; the quantity of this, however, depends very much upon what pathological changes the optic papilla and the nerve fibers had already undergone at the time of the operation. In the chronic simple glaucoma the iridectomy generally arrests the progress of the disease, and may produce an improvement of vision, although it does so but rarely. On general principles we may state that the earlier the operation is performed the greater may we expect its effect to be.

It is as yet an unsettled question why an iridectomy will lastingly reduce the intraocular pressure, although the fact is undoubted. It seems to be most likely that the explanation lies in the fact that the removal of a piece of iris tissue not only lessens the quantity of the blood-vessels, and, therefore, of blood within the eyeball, but also takes away a part of the obstacle to the draining of the fluids from the anterior chamber. It has been stated by Exner that a direct communication between the arteries and veins, without intervening capillary network, would take place in the parts of the iris directly wounded by the iridectomy. The writer, when reporting his studies on the process of healing after an iridectomy, had occasion to state that he had never been able to see such a condition. Arlt, in his recent book on glaucoma, takes pains to say that the writer's statements in regard to this question are of no value, since he had not injected the blood-vessels. The writer's paper on the question, however, states plainly that he injected most of the animals experimented upon with Berlin blue, and for the truth of the matter it is necessary to state here again that he was, and is to this day, unable to verify Exner's observations.

More recently Henderson has claimed that the iris wound after an iridectomy does not heal and sees therein the value of the iridectomy. In the writer's opinion, based on numerous examinations of eyes on which an iridectomy had been performed, the wound on the iris stump does heal as a rule.

A number of authors maintain that the scar in the corneo-scleral tissue is of more importance even than the excision of a piece of iris tissue (Wecker), and they consider this scar a means of continued filtration of fluids from the anterior chamber. No direct proof for this opinion has thus far been given, but there is no doubt that scar-tissue, when consolidated, is, as a rule, more compact than normal tissue. It would, therefore, seem that we have a right to expect an effect just opposite to the one here given as an explanation of the action of an iridectomy in glaucoma.

Whatever the explanation of the healing influence of an iridectomy in glaucoma may be, one thing is certain, that we have occasion to see cases in which a typically performed iridectomy has not been able to stay the progress of glaucoma, as well as cases in which a very imperfect operation has had the desired effect. This would seem to show that science will some day find a procedure which will supersede the empirical operation of iridectomy for glaucoma. At present, however, it seems to many, as yet, to be the safest and the most satisfactory measure in our hands.

Based on the theory that the corneoscleral or scleral incision necessary to perform an iridectomy was the main feature of this operation in glaucoma, and that the excision of a piece of iris tissue was wholly unimportant to the end in view, besides, of course, having other disagreeable features (Quaglino, Wecker, and others), simple sclerotomy, and either anterior sclerotomy or posterior sclerotomy have been proposed and introduced in place of iridectomy. The efforts which have been made to supersede the iridectomy by the sclerotomy have, however, failed. This failure is not only due to the danger arising from prolapse or from incarceration of the periphery of the iris in the corneoscleral wound, but also to the fact that the combined experience of many observers has shown that this operation is insufficient, and especially so in the inflammatory forms of glaucoma. It may be performed with more success in chronic simple glaucoma, and in cases in which an iridectomy has not been able to cut short the progress of the disease altogether, and in which a second and even a third iridectomy has by some authors been advocated. It may, furthermore, be considered of value in cases of glaucoma absolutum, when the pathological changes of the iris tissue no longer allow of the performance of an iridectomy.

Several authors have tried to replace iridectomy by an operation which aims at cutting the ciliary muscle (Hancock) or the tendinous portion at its insertion into the corneoscleral tissue. These procedures seem not only to be of doubtful value, but also to be fraught with danger from subsequent sympathetic ophthalmia. The latter objection has, however, also been urged against sclerotomy. A more recent procedure is excision of the superior cervical sympathetic ganglion as introduced by Jonnesco. This operation is still *sub judice*, having its ardent admirers as well as enemies. A careful critical paper on the subject by Ziehe and Axenfeld says that in all cases of glaucoma in which our present therapeutic measures have not sufficed, the extirpation of the cervical sympathetic is a justifiable and advisable experiment, although it does by no means afford help in every instance.

More recent statistics show that this operation, though theoretically well founded, has not justified the enthusiasm with which it was introduced, since its effect does not seem to be permanent.

It seems that a real progress in the operation for glaucoma has been made recently by the excision or trephining out (sclerectomy) of a piece of sclera (Lagrange, Elliott, and others), thus producing a permanent filtrating scar. This is usually combined with an iridectomy.

Aside from the operation, the general condition of a patient suffering from glaucoma ought to be attended to. He ought to be especially restrained from everything which may in his case be apt to act as an occasional cause for a glaucomatous attack. If there is—and this is the rule—an error of refraction or accommodation, or of both, it must be corrected. In fact it is claimed that careful attention to refractive errors as practised in this country has reduced the number of cases of glaucoma.

Glaucoma not always being easy to recognize, it will be always well to examine carefully, with regard to the possible presence of this disease, every patient who comes to his physician complaining of, and seeking relief from, neuralgia of the eye and head, combined with obscurations of sight and with nausea. ADOLF ALT.

Glen Alpine Mineral Springs.—El Dorado County, California.

ACCESS.—Southern Pacific to Truckee, thence Lake Tahoe Railway and Transportation Company's rail line and steamer to Tallac. Leaving San Francisco in the evening, travelers are due at Glen Alpine at 1 P. M. the next day. Or Southern Pacific to Placerville and auto stage to Tallac. The automobile route runs from Sacramento on State Highway to Tallac.

Back in the mountain fastnesses at a distance of seven miles from Lake Tahoe, and at an elevation of 6,700 feet above the sea-level, are Gilmore's Glen Alpine Mineral Springs and Health Resort. The daily steamer is met at Tallac by Glen Apline auto stage. The wild, rugged gorge in which the springs are situated runs back from Tahoe a distance of some ten miles. It is diversified throughout its length with varied scenes of beauty and grandeur, and terminates abruptly in a glacial amphitheatre. The region is rich in exquisite flowers and ferns. "Those dimpling lakes, with the wild beauty of their surroundings are sufficient to enthrall the heart of him who visits them; but if he be devoted to the rod and reel he will find an additional charm in the swarms of speckled beauties which sport in the clear depths and rise to the glancing fly."

This region has been opened to the public with great labor and expense by the construction of a wagon road as far as Glen Alpine Springs, and mountain trails to all the lakes, including a path for the ascent of Mount Tallac, which rears its head 9,716 feet above the level of the sea, and commands a wide and magnificient view of the distant peaks and numerous lakes. The climb to Pyramid Peak, elevation 10,020 feet, may be taken in one day. A few of the other climbs are Mt. Agassis, Mt. Echo, Keith's Dome, Ralston Cracked Crag, Richardson, Jack's, Dick's, and Angora Peaks. Good accommodations for guests will now be found at Glen Alpine Springs. The season is from about June first to about October first. Analysis by Dr. Anderson:

ONE UNITED STATES GALLON CONTAINS:

Solids.	Grains.
Sodium chloride	21.17
Sodium carbonate	32.75
Potassium carbonate	Trace.
Magnesium carbonate	9.96
Calcium carbonate	45.09
Calcium sulphate	4.10
Ferrous carbonate	1.80
Alumina	1.43
Borates	Trace.
Silica	2.50
Organic matter	Trace.
Total solids	118.80

Free carbonic acid gas, 138.36 cubic inches.
Temperature of water, 39.6° F.

The water is very palatable and sparkling. Its action is gently aperient and diuretic, and the water is useful in dyspepsia and torpidity of the bowels as well as in renal and cystic disorders. It contains sufficient iron to give it important properties as a ferruginous tonic. EMMA E. WALKER.

Glen Springs.—Schuyler County, New York.

POST-OFFICE.—Watkins. Hotel and sanitarium.

ACCESS.—Watkins is situated on the Northern Central Division of the Pennsylvania Railroad, on the Pennsylvania Division of the New York Central Railroad and on the main line of the Lehigh Valley Railroad, between Elmira and Rochester The Northern Central runs from Rochester to Baltimore, Philadelphia and Washington. It connects at Rochester with the New York Central, West Shore, Michigan Central and other railroads, at Canandaigua with the Auburn branch of the New York Central, and at Elmira with the Erie and the Delaware, Lackawanna and Western Railroad. This beautiful and modern health resort and watering-place stands upon a broad plateau 300 feet above Seneca Lake, whose winding

course it overlooks for nearly thirty miles. It is surrounded by pine forests and backed by an amphitheatre of hills rising in regular terraces to nearly 1,500 feet. At the foot of the hill, less than a quarter of a mile away, lies the village of Watkins, with its churches, shady streets, and lovely homes, while the entrance to the famous Watkins Glen and the landing of the Seneca Lake steamers are both within seven minutes' easy walking distance. Seneca Lake is one of the most remarkable bodies of water known. It is fed by deep springs, and has been frozen over only twice during the last century. For beauty of scenery and richness of coloring it has no superior, its shores are grand and picturesque, the sides thickly wooded in places, in others covered with friut orchards and vineyards. This great body of water, nearly forty miles long and from two to four miles in width, exerts an unquestioned modifying influence on the atmosphere, tempering it in winter and cooling and freshening it in summer. A remarkable feature of this region is the great number of its sunny days during the fall, winter, and spring. The record for 365 days has shown that there were only 55 cloudy days, and 17 of those were in May. These features tend to make the location a very desirable winter as well as summer resort. The Glen Springs Park comprises sixty acres of woodland and lawn, about equally divided, and one can wander for miles over well-built walks, obtaining from almost every point grand and beautiful vistas of lawn, lake, forest and glen. Within the park are bowling-alleys, tennis courts, croquet grounds, and golf links. Pleasant drives abound in every direction, while to those who prefer the water the fine, large steamers of the Seneca Lake Navigation Company, plying six times a day between Geneva and Watkins, afford every comfort and luxury. Good fishing is found in Seneca Lake, and within easy driving distance over good roads one can reach Keuka, Lamoka, Cayuta, and Little Lakes, all famous fishing resorts. The main building of the Glen Springs sanitarium, heated by steam and lighted by electricity and gas, consists of four stories and a basement, constructed in a substantial manner of brick and stone. There is also an annex. The two buildings are connected by a wide corridor enclosed in glass and heated in cold weather by steam. It affords ample space for exercise, and forms an excellent solarium during the winter months. These buildings are provided with all modern comforts and luxuries. On the grounds there are several large mineral springs which are used for drinking and bathing. The following analyses of the first three springs were made by Prof. S. A. Lattimore, of the University of Rochester.

Seneca Spring—Calcic.

One United States Gallon Contains:

Solids.	Grains.
Calcium carbonate	9.90
Calcium sulphate	.47
Magnesium carbonate	2.10
Sodium chloride	.12
Silica	.07
Iron oxide	Trace.
Total	12.66

The water is entirely free from organic matter. This spring is situated two hundred feet higher than the buildings. It flows about 4,000 gallons of water per hour, and is used in the buildings for general domestic purposes.

Salubria Spring—Muriated-Saline.

One United States Gallon Contains:

Solids.	Grains.
Sodium chloride	196.28
Calcium carbonate	19.68
Magnesium carbonate	.05
Silica	Trace.
Total	216.01

This spring issues from the rock at a depth of 250 feet, and resembles the class known in Germany as muriated (chloride of sodium) alkaline springs. It is somewhat similar to the waters of Vichy, Sachingen, and Bilin, but is more like those of Kissingen, Homburg, and Wiesbaden. The water has a stimulating effect upon the mucous membrane of the stomach and bowels and increases the flow of gastric juice and bile and promotes digestion and absorption. It has about the proper quantity of sodium chloride favorably to influence the process of osmosis. In large doses it is purgative.

Vulcan Spring.

One United States Gallon Contains:

	Grains.
Calcium carbonate	29.80
Magnesium carbonate	11.37
Iron carbonate	1.87
Sodium chloride	149.06
Alumina	Trace.
Silica	Trace.
Total mineral constituents	192.10

This water also contains much carbonic acid gas.

The analyses of the following springs, Glen Kissingen, Nauheim and Deer Lick Springs were made by D. W. Fetterolf, M. D., Demonstrator of Chemistry, Medical School, University of Pennsylvania.

Glen Kissingen Spring.

One United States Gallon Contains:

	Grains.
Sodium chloride	71.5189
Calcium bicarbonate	69.8269
Magnesium chloride	1.5575
Magnesium sulphate	2.4646
Potassium chloride	.1288
Ammonium chloride	.6243
Sodium iodide	.1336
Sodium bromide	Trace.
Iron bicarbonate	3.2074
Alumina	1.5683
Silica	.8167
Phosphoric acid as P_2O_5	Trace.
Total	151.8470

This is a clear, sparkling water, and issues from the rocks at a depth of 100 feet. It resembles the waters of Kissingen, and has diuretic, tonic, mildly aperient, and slightly alterative properties.

Nauheim Spring.

One United States Gallon Contains:

	Grains.
Sodium chloride	6941.8650
Calcium chloride	2718.4110
Magnesium chloride	685.1971
Ammonium chloride	131.7900
Potassium chloride	.7000
Sodium bromide	4.2001
Sodium iodide	1.0004
Barium bicarbonate	1.4980
Iron bicarbonate	14.3920
Alumina	13.4758
Silica	13.0004
Lithium chloride	Trace.
Sulphuric acid as SO_3	Trace.
Phosphoric acid as P_2O_5	Trace.
Total	10525.3298

This water constitutes a strong brine. It is quite remarkable for its large proportion of calcium chloride and its total freedom from calcium sulphate (gypsum). In its principal ingredients it resembles the brine springs of Michigan and the springs of Nauheim, Rehme, and Jaxtfelt. It may be classed as an iodo-bromated saline spring, and while not adapted for drinking purposes, is of great value for bathing. By charging the water with carbonic acid gas it

becomes very similar to the Nauheim waters, and the treatment of glandular and rheumatic troubles, gout, lumbago, and sciatica, as well as the Schott method in chronic diseases of the heart, is carried out at Glen Springs. This water is also employed in the electro-chemical and electro-vapor baths, douches, and sprays. The spring is said to have its origin about 1,706 feet below the surface of the earth.

DEER LICK SPRING.—ALKALINE, SALINE, CHALYBEATE.

ONE UNITED STATES GALLON CONTAINS:

	Grains.
Sodium chloride	117.0200
Calcium bicarbonate	70.5863
Barium bicarbonate	.4413
Magnesium chloride	26.5715
Potassium chloride	.1448
Ammonium chloride	.5018
Sodium bromide	1.2320
Sodium iodide	.2177
Lithium chloride	Trace.
Iron bicarbonate	12.1920
Alumina	.4958
Silica	.6067
Sulphuric acid as SO_3	Trace.
Phosphoric acid as P_2O_5	Trace.
Total	230.0099

This water is clear and sparkling, without odor, and with a slightly astringent, mildly saline taste. Containing, as it does, besides chloride of sodium and iron, the rare ingredients of iodine and bromine (in combination), it may be ranked as a ferro-iodo-bromo-muriated spring. It is also rich in carbonic acid gas. It resembles in many respects the waters of Kreuznach, Hall, Duerkheim, and Krauenheit. It is an excellent drinking-water and, unlike many of the foreign iodo-bromated waters, may be taken as it flows without dilution. The Deer Lick water possesses tonic, alterative, diuretic, and mildly aperient properties. Tissue metabolism is promoted and the red cells of the blood are increased. Its physiological action fits it for use in anemia, neurasthenia, chronic renal diseases, glycosuria, and chronic diseases of the uterus.

EMMA E. WALKER.

Glen Summit Springs.—Luzerne County, Pennsylvania.

POST-OFFICE.—Glen Summit Water. Hotel.

ACCESS.—Viâ the Central Railroad of New Jersey and the Lehigh Valley Railroad, about 150 miles from New York and 125 miles from Philadelphia. Glen Summit Springs Hotel is at Glen Summit Springs on the Lehigh, and is about three-quarters of a mile from the Glen Summit Springs and Glen Summit Water on the New Jersey Central.

This attractive summer resort is on the summit of the Nescopeck Mountain, 2,000 feet above tide-water, and about nine miles from Wilkesbarre by carriage drive. The romantic scenery of the surrounding country and its easy accessibility, coupled with an excellent modern hotel furnished with all the recent improvements, have of late years served to bring the place into well-deserved prominence. The charming surroundings and pure, invigorating mountain air offer an enticing refuge from the toils and cares of city life during the hot weather. Numerous cases are cited of the apparent complete arrest of incipient lung disease after a few weeks spent here. The springs about Glen Summit are of the ascending variety, welling up along the lines of jointing in the Catskill formation from far down in the subterranean recesses below. The temperature of the water is acquired from the rocks at depths sufficient to be beyond the influence of surface temperatures, and is cold enough to cause an unpleasant chill to the hands when submerged for a few seconds. An examination, however, will show that these waters owe their value rather to their purity and palatability than to their chemical ingredients. The following analysis was made by Prof. W. H. Dean, chemist, of Wilkesbarre, in 1913:

	Parts in 100,000.	Grains per gallon.
Silica	.335	.195
Iron and alumina	.010	.006
Calcium	.339	.198
Magnesium	.110	.064
Sodium and potassium	.090	.052
Chlorine	.280	.163
Sulphate radicle	.587	.342
Nitrates	.000	.000
Nitrites	.000	.000
Free carbonic acid	.750	.438
Total solids on evaporation	2.300	1.340
Loss on ignition	.550	.320
Fixed residue	1.750	1.020
Bacteria per c.c. (72 hr. growth)	1	

This shows a very pure and valuable water for domestic uses. The water is soft containing only a trifle more then one grain of solids to the gallon, and will keep unchanged for an indefinite length of time. Among other excellent pure-water springs in the neighborhood are the "Great Indian" Spring, yielding over 4,000 gallons hourly (it supplies the hotel); the "Twin" Springs, the "Bear" Spring, and the "Counterfeiter's" Spring. There are also other springs which have not been named.

EMMA E. WALKER.

Glenn Springs.—Spartanburg County, South Carolina.

POST-OFFICE.—Glenn Springs. Hotel and cottages.

ACCESS.—From Spartanburg, a distance of 12 miles by automobile line. The Springs are six miles from White Stone on the Asheville and Columbia branch of the Southern Railway, by hack line. There is a prospect for an electric car line from Spartanburg.

These springs are located in a charming section of the country, broken by granite and sandstone hills. The elevation is about 1,000 feet above the sea-level. Many improvements have recently been added, the hotel having been greatly enlarged and comfortable cottages built. Many additional improvements are under way, and when completed Glenn Springs will, it is claimed, bid fair to compete with the leading spas of the country. The following analysis of the Glenn Springs water was made by Professor J. W. Mallet, M. D., Ph. D., LL. D., F. R. S., of University of Virginia:

	Parts per million.
Potassium sulphate	7.26
Sodium sulphate	44.62
Lithium sulphate	.63
Calcium sulphate	1542.80
Calcium chloride	3.82
Calcium phosphate	.08
Calcium nitrate	.41
Calcium carbonate	48.57
Strontium carbonate	Trace.
Magnesium carbonate	12.15
Ammonium carbonate	Trace.
Iron carbonate	.23
Manganese carbonate	Trace.
Aluminum hydroxide	.09
Metasilicic acid	41.14
Organic matter	Trace.
	Cubic centimeters per liter.
Dissolved gases.	
Nitrogen	11.34
Oxygen	5.72
Carbon dioxide	16.26
	33.32

Glenn Springs Mineral Water is a natural alkaline, saline, calcic water. It has been in use many years. Numerous wellknown physicians of South Carolina attest to its virtues, especially in disorders of the alimentary tract, dyspepsia, diarrhea, dysentery, and hemorrhoids. It is said to be very useful in functional uterine affections, dysmenorrhea, amenorrhea, and leucorrhea, as well as in torpidity of the liver, biliousness, malaria, rheumatism, and general debility. The water is used commercially. The season lasts from June first to October first.

EMMA E. WALKER.

Glenwood Springs.—Garfield County, Colorado.

POST-OFFICE.—Glenwood Springs. Hotels: The Colorado and numerous smaller hotels.

ACCESS.—Viâ the Denver and Rio Grande and the Colorado Midland Railroads. The winter climate is bracing and delightful. The weather is dry and cold, bright and clear. The elevation is about 5,600 feet above sea level. Although the treatments at the Springs may be advantageously taken at any season of the year, the months of May, June, September and October are strongly recommended to patients as being especially pleasant and favorable because of their even temperature. (See also the article on *Colorado*. Vol. III., p. 211.)

The following analysis of the waters at Glenwood Springs was made by Prof. Charles F. Chandler of New York.

YAMPAH SPRING—MURIATED, SALINE, SULPHURETED.
ONE UNITED STATES GALLON CONTAINS:

Solids.	Grains.
Sodium chloride	1,089.83
Magnesium chloride	13.09
Sodium bromide	.56
Sodium iodide	Trace.
Calcium fluoride	Trace.
Potassium sulphate	24.04
Calcium sulphate	82.38
Lithium bicarbonate	.22
Magnesium bicarbonate	13.55
Calcium bicarbonate	24.37
Iron bicarbonate	Trace.
Sodium phosphate	Trace.
Sodium biborate	Trace.
Alumina	Trace.
Silica	1.97
Organic matter	Trace.
Total	1,250.01

Carbonic acid gas and sulphureted hydrogen are copiously discharged from the springs, and are retained in the bottled water in varying quantities. The famous Hot Springs from which the town derives its name 'boil' out of the ground on both sides of the Grand River and are about fifty in number. The appearance of boiling is due to the pressure of carbonic acid and sulphureted hydrogen.

The temperature of the Yampah, the largest spring of the group, and of the "Chicken-broth" or "Cocktail" spring, is 127° F. The specific gravity of the former when cooled down to 83° F. was 1.013, and of the latter a trifle less. The flow of Yampah Spring is 2,889 gallons per minute. The estimated total flow of Glenwood Springs is 6,000 gallons per minute. The waters are highly radio-active. That the waters here are strongly impregnated with sulphureted hydrogen is amply attested by the heavy deposit of sulphur crystals on stones seen in the springs, and on the surrounding sandstone walls. In the Yampah Spring the gas is in sufficient quantity to impart a decided bluish tinge to the water, rendering it slightly opalescent. The atmosphere immediately surrounding the springs is heavily charged with the escaping vapor. The waters of the springs in flowing into the great swimming-pool—the largest out-door pool in the world—are cooled to some extent by contact with the air and by evaporation, but the temperature is further lowered by an artificial cold-water geyser near the western end of the basin, supplied from a nearby mountain reservoir. An average temperature of from 84° to 94° F. is thus maintained, and bathing may be indulged in the year round. Another interesting and unique feature of Glenwood Springs should not pass unnoticed. Across the Grand River from the Hotel Colorado, and two or three hundred yards upstream, is the entrance to a cave which extends for a considerable distance under the mountain. This cave has a natural temperature of about 112° F., and the atmosphere is saturated at all times with the vapor of water strongly impregnated with sulphur like that at the springs. After one has remained for a few minutes in the cave the surface of the body becomes bedewed with a profuse perspiration. Advantage has been taken of this ready-made Russian-bath vapor chamber, and a stone bath-house with the requisite adjuncts has been constructed at its entrance. Here are the resident physician's office, and laboratory, also a medical gymnasium for Swedish movements, with instructors, masseurs and masseuses. The cave itself is lighted by electricity, and attendants are on hand to supply the wants of bathers either in the caverns or in the private rooms.

As we have thus seen, the waters at Glenwood, besides being saline-alkaline and sulphureted, are highly thermal. The waters have proved very beneficial in cases of chronic rheumatism, gout, cutaneous and renal diseases. They are also very useful in diseases of the liver, gastro-intestinal disorders, obesity, nervous diseases; alcohol, nicotine, and blood poisoning, metallic poisoning, and in catarrh of nose, throat and larynx. Although these springs have been developed principally for bathing purposes, the waters are useful both internally and locally. They are used commercially. In common with all hot baths, these waters are contraindicated in fatty degeneration of any important structure, in atheroma, aneurysm, or structural heart trouble, and in the predisposition to pulmonary, cerebral, gastric, or intestinal hemorrhage. Many sources of recreation are at the disposal of the guests, among which are riding, driving, walking, out-door bathing, tennis, polo, golf, fishing and shooting. Many camping parties go from the Springs into the regions nearby

EMMA E. WALKER.

Gliadin.—Alcohol-soluble proteins are chiefly important as constituents of the cereal grains. The best known example of this group of proteins is gliadin which occurs to the extent of approximately fifty per cent. of the proteins of the wheat kernel. The gliadin and glutenin (proteins insoluble in all neutral solvents, but readily soluble in dilute acids and alkalies) together constitute the gluten of flour.

F. P. U.

Glioma.—A glioma is a new growth which arises from the supporting tissue of the central nervous system and which is therefore composed principally of proliferating neuroglia and its accompanying blood-vessels. Since the glial cell, the essential and characteristic element of the glioma, is of ectodermal origin, it would be altogether proper from the standpoint of embryology to class the various types of gliomas with the epithelial tumors derived from the epiblast. By some writers, this course has been followed. However, in structure, manner of growth and life history, the simple gliomas closely resemble the ordinary connective-tissue tumors and it is with

tion group that the glioma is usually described. In a similar manner, the more cellular types correspond to sarcomas.

The glioma is by far the most common brain tumor. Tooth found that 49.2 per cent. of 258 microscopically verified brain tumors were gliomas. In his statistics gliomata constituted 58.7 per cent. of all neoplasms of the hemisphere, 50 per cent. of those of the mid-brain

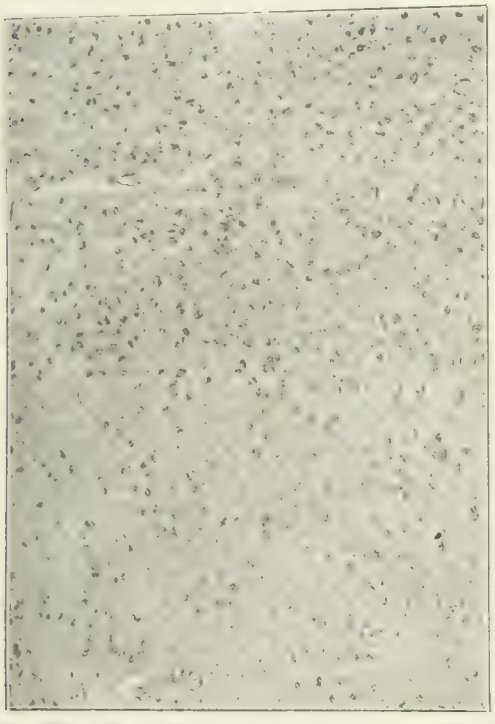


Fig. 2812. Microphotograph of a Simple Glioma. Relatively low cellular magnification to show the scarcity of nuclei and the preponderance of intercellular fibrils.

and 38.9 per cent. of those of the cerebellum, pons, etc. He found that the glioma incidence is highest in the age period twenty-one to forty. Although most frequently found in the brain itself the glioma occurs also in the spinal cord, in the retina and very rarely along certain cerebral nerves and in the region of the coccyx, where it arises from remains of the neural canal.

In the gross, the glioma is usually a solitary tumor, varying from the size of a pea to that of a walnut. In rare instances it may reach the size of the fist or larger. These tumors are usually without a capsule of any sort although the firmer examples may prove exceptions to this rule. In color the glioma may so closely resemble the normal brain tissue that only the absence of the usual differences between various structures in the brain substance gives evidence of the presence of the tumor. In such cases it may be quite impossible to recognize the boundaries of the growth as it passes imperceptibly into the surrounding tissue. Other gliomas are greyish pink, yellowish pink, or even dark red and may then be readily recognized. This deeper color may be due to a high degree of vascularity in the neoplasm or to areas of hemorrhage. In many cases the tumor shows a higher degree of translucency than the normal brain tissue and this difference in appearance is of assistance in recognizing the presence and extent of the new growth.

In consistency, also, gliomas exhibit as wide a range of variation as in color. All gradations are found from those which are very soft, because of their high degree of cellularity or areas of necrosis and cystic degeneration, to firm tumors in which the fibrillar substance is relatively increased over the cells. It must be noted that various portions of the same tumor may differ widely in this respect.

In the microscopical section a fully developed glioma of the usual type shows numerous cellular elements not differing greatly from normal glial cells. Round or bluntly oval nuclei, somewhat vesicular but staining readily, are surrounded by small masses of protoplasm, which are seen with some difficulty in material prepared according to the usual methods. In teased preparations examined in the fresh state a branching cell body can be demonstrated. These glial cells are enmeshed in a loose but very fine reticulum of glistening fibrils. The exact relationship of these fibrils to the cell bodies has been much discussed. The best work seems to demonstrate that they neither begin nor end in the cell body by which they were produced but that they adhere to it at some point along their course. In addition to cells and intercellular fibrillæ, blood-vessels are the only elements in the simple type of glioma. Such a tumor closely resembles a diffuse gliosis in its microscopical features and in some cases differentiation is not readily

Fig. 2813. Microphotograph Showing much Higher Magnification of the Same Specimen of Glioma as in Fig. 2812. The rich network of intercellular fibrils is well shown.

possible. The more diffuse gliomas infiltrate the surrounding tissues and blend with the normal neuroglia so gradually that even in the microscopical section it is often quite impossible to define their limits.

From the type of glioma above described the most frequent variation is in the direction of increase in the cellular elements at the expense of the intercellular fibrillæ. Such a tumor is much softer than the simple glioma and upon section is seen to be richly nucleated. Oftentimes the nuclei show a tendency to be placed in crescentic or circular groupings in which

the long axes of the nuclei are radially arranged. Rarely this grouping takes the form of a rosette about a small blood-vessel. These highly cellular gliomas are much softer than those in which the intercellular substance is more in evidence. Such a tumor is therefore classed as a medullary glioma or *glioma molle* while a firmer neoplasm with fewer cells is spoken of as *glioma durum*. Although this is the usual classification of gliomas it must be borne in mind that all gradations between the two types are to be found, oftentimes in different portions of the same tumor mass, and that this classification therefore loses much of its weight. These richly nucleated gliomas with little intercellular substance and many blood-vessels are sometimes not readily differentiated from sarcomas. In fact, some authors put them in that class while such terms as *gliosarcoma* and *glioma sarcomatodes* are used to designate tumors of apparently intermediate position. Undoubtedly some of the growths included under these terms have been purely sarcomatous, while others have been described as exhibiting a rapid proliferation of the perivascular connective tissue in addition to the formation of an atypical neuroglia. In strict usage, the term *gliosarcoma* should be reserved for this latter type alone, unless, as Adami suggests, the term sarcoma is used only in the general histologic sense.

Certain other descriptive terms are applied to some gliomas. Those in which "brain sand" is found are called *psammogliomas*. To those which are edematous the term *myxoglioma* is sometimes incorrectly applied. A *glioma telangiectaticum* is one with numerous and widely dilated blood-vessels and if it has large hemorrhagic areas it may be described as a *glioma hæmorrhagicum* or *glioma apoplecticum*.

A related variety is the *neuroglioma gangliocellulare* or *neuroglioma ganglionare*, a tumor of the central nervous system which differs from the simple glioma in that it contains nerve fibers and ganglion cells in addition to a proliferating neuroglia. It is not at all certain that the ganglion cells and nerve fibers are not mere inclusions in a developing glioma and play no active part in the neoplastic process. For this reason the term neuroglioma has come into disfavor and has been dropped entirely by some writers. The appearance may depend entirely upon some developmental anomaly. In a similar way can be explained the occurrence of mixed tumors, in part gliomatous and in part epithelial, in which gland-like spaces are scattered throughout the atypical glial tissue. A number of these very interesting tumors have been described and in some it has been possible to demonstrate that the epithelial elements have had their origin from the ependyma. Such a growth is called a *neuroepithelioma gliomatosum*.

Various degenerative changes may occur in gliomas. The most common of these is *cyst-formation*. This process begins with a thinning of the stroma and a coalescence of the tissue spaces thus formed. Such cysts may be single or multiple and may attain a large size Areas of *necrosis* are also frequently noted in gliomas. These result from obliterative changes in the blood-vessels, a process which is frequently to be noted in gliomas of long standing.

As with all other brain tumors, the *symptoms* produced by a glioma readily fall into two groups; those which are dependent upon either increased intracranial pressure or upon fluctuations in intracranial pressure, and those which are dependent upon interference with the functioning of certain cerebral areas or of the fiber tracts leading to or from them. Of the general symptoms, optic neuritis of the "choked disc" type, headache, stupor, vomiting, vertigo, slow pulse and general convulsions are most frequently of diagnostic importance. The localizing symptoms are most variable, depending upon the region involved. Such symptoms may be entirely absent or there may be Jacksonian epilepsy, paralysis, aphasia, apraxia, or amblyopia, making it possible to localize the new growth.

The simple gliomas, both of the hard and soft varieties, are relatively benign tumors in that they show no tendency to set up metastases. Sometimes they are slow growing and seem to have periods of latency. In other cases they soon reach a large size and produce severe symptoms at an early date. They grow by infiltrating the brain substance and replacing it instead of compressing the surrounding tissues by an expansive growth, as do the sarcomas. The typical glioma does not invade the meninges or the bones of the skull.

Whether a glioma is a suitable one for surgical *treatment* depends upon its location, size and histological character. The firmer types, those which are less cellular and correspond more nearly to the mature connective tissue tumors of mesenchymal origin, have been successfully removed in a number of cases. Some of these patients have lived several years without evidence of a recurrence. Brain puncture is frequently made use of in obtaining a tissue specimen for microscopical examination, although it sometimes seems that even this comparatively slight surgical interference serves to awaken a latent malignancy. In cystic gliomas temporary relief of a high degree is sometimes afforded by puncture and drainage. No general rule in regard to surgical intervention can be laid down; each case must be considered upon its own merits.

The true glioma of the *spinal cord* usually arises in the central portion of the cervical cord and often can be distinguished from a secondary gliosis by its sharper boundary. Through cystic changes in the tumor the picture may be that of *syringomyelia*. However, such a condition must be distinguished from syringomyelia with secondary proliferation of the neuroglia. (See *Syringomyelia*.)

The so-called glioma of the *retina* must be mentioned here, for it is by this title that it is commonly known. It differs very much from the ordinary gliomas and it is doubtful if it properly belongs in this group. It rarely contains typical glial cells and intercellular fibrils may be entirely absent. The numerous small cells composing the tumor are radially arranged about the smaller blood-vessels and rosettes of cells are much more constantly found than in cerebral gliomas. These rosettes consist of groups of cells radially arranged about a lumen which is lined by a clear protoplasmic membrane. These formations are usually interpreted as representing the rods and cones of the retina. This retinal tumor appears as grayish or reddish-gray nodules projecting into the vitreous from the retina. If allowed to grow it may completely fill the eyeball and even project externally, or it may infiltrate the sclera and extend into the orbit and along the optic nerve into the cranium. Thus it differs from the simple glioma in its power to infiltrate tissues other than those of the central nervous system, and, unlike a simple glioma, it may give rise to metastases. The retinal glioma sometimes affects both eyes simultaneously, is most frequent in children under the age of five years, and may exhibit a marked tendency to occur in successive children of the same family. An early enucleation or exenteration offers the only hope of staying the progress of the disease.

CARL VERNON WELLER.

Glion.—See *Montreux*.

Glisson, Francis.—Celebrated English anatomist and one of the first to formulate the modern doctrine of irritability. Born in Rampisham, Dorsetshire, England, in 1597. He received the degree of Doctor of Medicine from the University of Cambridge, and somewhere about the year 1635 he was made Professor

of Medicine and Anatomy in the same university, a position which he held for many years. At the beginning of the Civil War he retired to Colchester and lived in that city while it was being besieged by the Parliamentary troops. After the surrender he settled permanently in London and was a prominent figure among the scientific men who founded the Royal Society. He died in 1677, at the age of eighty.

Glisson's name is perpetuated in the term "Glisson's capsule"—the fibrous capsule of the liver. Of his published writings the following deserve to receive special mention: "Anatomia hepatis, etc.," London, 1654; and "Tractatus de natura substantiæ energetica, seu, de vita naturæ, etc.," London, 1672.

A. H. B.

Globulins.—The globulins constitute a great group of the simple proteins, being differentiated principally from the albumins by being insoluble in pure water. As a rule the albumins and globulins are very often associated, as for example in the blood serum, in egg white, etc. In general the globulins predominate in animal tissues and plants whereas the albumins are most abundant in the animal fluids (blood, etc.). The use of appropriate prefixes serves to indicate the origin of the globulins, as ovoglobulin, serum-globulin, lactoglobulin, etc. F. P. U.

Glossina.—The genus of the tsetse-flies, which is confined to Tropical Africa and Arabia. The eyes of these insects are large and bare; the proboscis projects forward horizontally. The larvæ are born alive and pupate without feeding. *G. palpalis* carries *Trypanosoma gambiense*, the cause of sleeping sickness. See *Insects, parasitic.* A. S. P.

Glottis, Edema of.—See *Laryngitis, Acute.*

Glucosamine.—This substance $CH_2.OH$ is a derivative of glucose and is an α-amino sugar.

$$\begin{array}{l} (CH.OH)_3 \\ CH.NH_2 \\ COH \end{array}$$

It has a reducing action similar to glucose but is not fermentable. It was first prepared from chitin by the action of concentrated hydrochloric acid. Recently it has been obtained as a cleavage product of several mucin substances and proteins.

F. P. Underhill.

Glucose.—See *Dextrose.*

Gluge, Gottlieb.—A distinguished Belgian worker in the domain of pathological histology. Born of Jewish parents in Brakel, northern Prussia, on June 18, 1812. He received his doctor's degree from the University of Berlin in 1835, and in 1838 he was appointed Professor in the University of Brussels, Belgium. Of his numerous published writings the following deserve to receive special mention: "Pathologische Histologie," Jena, 1850 (an English translation of this work by Joseph Leidy was published in Philadelphia in 1853); "La nutrition, ou la vie considérée dans ses rapports avec les aliments, etc.," Bruxelles, 1856; and "Abcès de la rate; guérison," 1870. He died in Nice, in the south of France, December 22, 1898. Gluge's name is assured a permanent place in the history of medicine through his discovery of the bodies known as "Gluge's corpuscles." A. H. B.

Glutelin.—A glutelin is a simple protein which is insoluble in all neutral solvents but readily soluble in very dilute acids and alkalies. The most typical example is perhaps glutenin of wheat flour. The glutelins occur in abundance in the seeds of the cereals.

F. P. U.

Gluten is that part of wheat flour which is composed of the proteins gliadin and glutenin. The baking qualities of the flour are directly influenced by the proportions of these proteins present.

F. P. U.

Glutoid Capsules are gelatin capsules which have been hardened in formalin. They are used for the administration of drugs (such as copaiba, eucalyptus, creosote, guaiacol, etc.) which it is desired to have set free in the intestine, and not in the stomach. These capsules are made in three grades, according to the degree of resistance to the action of the gastric juice. R. J. E. Scott.

Glutol, also called *glutoform*, and *formaldehyde-gelatin*, is an odorless, yellowish powder, formed by the action of formaldehyde on gelatin. It has been used as a dusting powder and as a wound disinfectant, the action being due to the setting free of the formaldehyde. Its action causes pain, and the setting free of the formaldehyde is not without danger. It must be remembered that formaldehyde is obtained by the oxidation of methyl alcohol. R. J. E. Scott.

Glycerin.—Glycerin, or glycerol, $C_3H_5(OH)_3$, is, chemically, a triatomic alcohol, and results from the decomposition of natural fats by alkalies. The United States Pharmacopœia recognizes under the title *Glycerinum*, Glycerin or Glycerol, "a liquid obtained by the decomposition of vegetable or animal fats, or fixed oils, and containing not less than ninety-five per cent. of absolute glycerol." Glycerin can be obtained as a by-product in the making of lead plaster or of soap, but is derived in purest condition by acting on fats with water at a high temperature, under pressure. Under those conditions the fats break up into glycerin and fatty acids. Glycerin so prepared is known as *distilled glycerin*, and the famous Price's glycerin is of such kind. Glycerin appears as "a clear, colorless liquid, of a thick, syrupy consistence, smooth to the touch, odorless, sweet to the taste, and producing a sensation of warmth in the mouth; when exposed to the air, it absorbs moisture. Specific gravity: not less than 1.246 at 25° C. (77° F.). Soluble, in all proportions, in water and alcohol; also soluble in a mixture of 3 parts of alcohol and 1 part of ether, but insoluble in ether, chloroform, carbon disulphide, petroleum, benzin, benzene, and fixed or volatile oils" (U. S. P.). On heating, glycerin undergoes some decomposition: boils at 329° F., and finally is wholly decomposed and dissipated.

In its medicinal relations glycerin is unique, because of the following combination of qualities: It is at once viscid, non-volatilizable, unalterable on exposure, antiseptic yet non-poisonous, and has an unusual range of solvent powers, dissolving bromine, iodine, sulphur iodide, the fixed alkalies, lime, tannic and other vegetable acids, many vegetable organic principles, such as salicin and santonin, sugar, gum, and pepsin, and very many inorganic salts. Physiologically glycerin, in concentrated condition, is somewhat irritant to very sensitive parts, probably because of abstraction of water from the tissues; but upon ordinary surfaces it is perfectly bland. Swallowed by the human subject in quantities of an ounce or more, glycerin produces no other effect than a very mildly laxative action; but experimentally administered to the lower animals it proves toxic, producing tetanus in the frog, apparently from direct action upon the muscular tissue (Amidon: *Archives of Medicine*, October, 1881), and varied signs of nervous

derangement in rabbits and dogs, even to death by conjoint failure of respiration and heart action.

The uses of glycerin are, pharmaceutically, as a solvent, preservative, and sweet-tasting viscid addition to fluid preparations, or pill masses; and surgically, as an antiseptic, bland, and unalterable viscid application to wound surfaces and sores. Medically, glycerin has been used as a laxative in cases of hemorrhoids, as a preventive of flatulency, pyrosis, and the fermentation of the ingesta in the alimentary canal (Ringer and Murrell), and as a harmless sweetening addition to foods in cases of diabetes mellitus. A reputation which the substance once enjoyed, of tending directly to oppose the morbid process of diabetes, is now no longer credited. Glycerin may be given internally in quantities varying from a teaspoonful to a tablespoonful.

The United States Pharmacopœia makes official *Suppositoria Glycerini*, Suppositories of Glycerin. These suppositories are compounded of glycerin, with a little sodium carbonate and stearic acid, and each suppository contains three grams (about 45 grains) of glycerin. They are used for the relief of constipation, but should not be employed habitually, for fear of irritating the bowel.

Certain solutions of substances in glycerin constitute pharmacopœial preparations called *Glycerites*.

EDWARD CURTIS.
R. J. E. SCOTT.

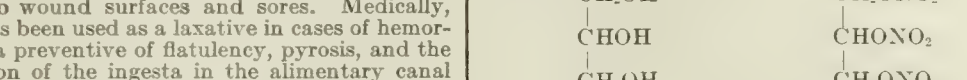
Glycerita.—A glycerite (*glyceritum*) is a mixture of medicinal substances with glycerin. The glycerite of starch is a semi-solid mass; the remaining official glycerites are solutions. They are useful preparations and can be diluted with water or alcohol without precipitation. The United States Pharmacopœia contains six glycerites, and the National Formulary also contains six.

GLYCERITA OF THE U. S. PHARMACOPŒIA AND NATIONAL FORMULARY

Glyceritum acidi tannici (glycerite of tannic acid).	U. S. P.	Tannic acid, 20; glycerin, 80.
Glyceritum amyli glycerite of starch).	U. S. P.	Starch, 10; water, 10; glycerin, 80.
Glyceritum bismuthi glycerite of bismuth.	N. F.	Bismuth subnitrate, 156; nitric acid, 148; tartaric acid, 236; sodium bicarbonate, 266; glycerin, 500; distilled water, q. s. ad 1,000.
Glyceritum boroglycerini (glycerite of boroglycerin).	U. S. P.	Boric acid, 31; glycerin, q.s. ad 100.
Glyceritum ferri, quininæ et strychninæ phosphatum. (glycerite of the phosphates of iron, quinine and strychnine).	U. S. P.	Soluble ferric phosphate, 80; quinine, 104; strychnine, 0.8; phosphoric acid, 200; glycerin, 500; water, q. s. ad 1,000.
Glyceritum guaiaci (glycerite of guaiac).	N. F.	Guaiac, 85; solution of potassium hydroxide, 65; glycerin, 650; water, q. s. ad 1,000.
Glyceritum hydrastis (glycerite of hydrastis).	U. S. P.	Hydrastis, 100; glycerin, 50; alcohol and water, q. s. ad 100.
Glyceritum pepsini (glycerite of pepsin).	N. F.	Pepsin, 85; hydrochloric acid, 10; purified talc, 15; glycerin, 500; water, q. s. ad 1,000.
Glyceritum phenolis (glycerite of phenol).	U. S. P.	Liquefied phenol, 20; glycerin, 80.
Glyceritum picis liquidæ (glycerite of tar).	N. F.	Tar, 63; magnesium carbonate, 125; glycerin, 250; alcohol, 125; water, q. s. ad 1,000.
Glyceritum tragacanthæ (glycerite of tragacanth).	N. F.	Tragacanth, 125; glycerin, 775; water, 185.
Glyceritum vitelli (glycerite of yolk of egg).	N. F.	Fresh yolk of egg, 45; glycerin, 55.

R. J. E. SCOTT.

Glyceryl Trinitrate.—This substance, better known as nitroglycerin, called also glonoin, would be more correctly named trinitroglycerol. Reference to the accompanying formulæ will show the relation of nitroglycerin to glycerin:



Glycerin. Nitroglycerin.

Nitroglycerin is made by the action of nitric and sulphuric acids upon glycerin, and is a transparent, colorless, dense oily fluid, of about the specific gravity 1.6; slightly soluble in water, but freely soluble in ether or alcohol. It is slightly volatile, inodorous, and of a sweet, pungent, aromatic taste. Upon concussion, it explodes with extreme violence. Nitroglycerin itself is not official as a medicine, but the United States Pharmacopœia recognizes a one-per-cent. alcoholic solution of the substance under the title *Spiritus Glycerylis Nitratis*, Spirit of Glyceryl Nitrate, or Spirit of Nitroglycerin. This spirit presents only the physical characteristics of alcohol, in appearance, taste, and smell, and is entirely non-explosive. But if some of it be spilled, so that the alcohol has a chance to evaporate, the nitroglycerin will become concentrated, and a dangerous explosion becomes possible. The spirit should, therefore, be handled with great care. If, through accident, it is spilled, a solution of potassium hydroxide should be at once poured over it; this will produce two comparatively harmless substances, glycerin and potassium nitrate:

$$C_3H_5(ONO_2)_3+3KOH=C_3H_5(OH)_3+3KNO_3$$

It should be kept in tin cans instead of in glass bottles, and these should be well stoppered and stored in a safe and cool place, away from exposure to light or fire.

The effects of a one-per-cent. solution of nitroglycerin upon the animal system are, in kind, exactly those of the nitrites (see *Nitrites*), with the additional symptom of a severe and obstinate headache. In rapidity of action, nitroglycerin occupies a position between amyl nitrite on the one hand, and the nitrites of the alkali metals on the other. The agent is powerful; a single drop of the one-per-cent. solution taken upon the tongue produces within three or four minutes a transient feeling of cerebral fulness and frontal pain, and a dose of four or five drops quickly determines a full nitrite derangement—flushed face, throbbing arteries, violent and disorderly heart action, hurried respiration, and splitting headache. Overdosage is extremely dangerous, as shown by a reported case in which, after a dose of two and a half drops of a five-per-cent. solution, the typical nitrite effects were quickly succeeded by sickness, faintness, and coma with stertorous breathing. The heart's action became alarmingly weak, but the patient finally recovered.

Nitroglycerin produces thus exactly the effects of a nitrite, and accordingly the inference is that in the career of the compound in the animal economy it suffers change into a nitrite, and as such nitrite exerts its activity. This subject of a possible chemical conversion of nitroglycerin within the system was studied by Matthew Hay (*Practitioner*, June, 1883), who found that nitroglycerin is decomposed by alkalies and alkaline carbonates, with the conversion of two-thirds of its nitric acid into nitrous, which nitrous acid then combines with the alkali to form a nitrite of the same. This reaction, furthermore, Hay was able to produce by treating a one-tenth-per-cent. solution of nitroglycerin in water with freshly drawn defibrinated blood, and digesting the mixing for forty minutes in an oven at a temperature ranging between 104° and 113° F. Such mixture assumed

the peculiar chocolate color of nitrite poisoned blood, and by analysis, after an hour's digestion, nearly the whole of the nitroglycerin present was found to have undergone decomposition.

Nitroglycerin thus seems to be, for the pharmacologist and physician, but a nitrite-furnishing compound, whose distinguishing feature is solely the extraordinary intensity of its action, a feature which Hay accounts for by the fact that nitroglycerin is, by the peculiarity of its composition, exempt from the decomposition by the acid of the gastric juice to which nitrites are liable—a decomposition which always renders inert a certain proportion of each dose of a nitrite swallowed as such.

The therapeutic applications of nitroglycerin are those of the nitrites. The remedy has been used with benefit in angina pectoris, asthma, and epilepsy, especially in *petit mal*, and also in the anemic form of migraine, and in nephritis attended with a hard, corded pulse. The dose, in an untried subject, should be at first but a single drop of the customary one-per-cent. alcoholic solution, to be repeated every fifteen minutes until four or five drops shall have been taken or relief experienced. In habitual use, as for epileptics, the dose will very likely require gradual increase. At the rate of an additional drop per dose each month so large a dosage as twelve drops three times a day of the one-per-cent. solution has been taken without the production of undue derangement.

EDWARD CURTIS.
R. J. E. SCOTT.

Glyciphagus.—A genus of mites, *Tyroglyphidæ*, found in flour, sugar, etc. *G. prunorum* and *G. domesticus* cause the grocer's itch. See *Arachnida*.

A. S. P

Glycocoll.—Glycocoll, $CH_2.NH_2.COOH$, aminoacetic acid (glycine) is a derivative of protein formed during pancreatic digestion or by hydrolytic cleavage. It is the compound that unites with any benzoic acid entering the body to form hippuric acid.

F. P. U.

Glycogen.—Glycogen, $C_6H_{10}O_5$, was first discovered by Claude Bernard who called it animal starch. It is a complex carbohydrate closely related to the starches or dextrins. It forms an amorphous, white, tasteless and odorless powder which gives a characteristic opalescent solution with water. On treatment with iodine a solution of glycogen yields a wine-red color. This reaction is especially sensitive in the presence of small quantities of sodium chloride. It is precipitated from its solutions by addition of an equal volume of ninety-five per cent. alcohol. By diastatic enzymes glycogen is changed into maltose or dextrose depending upon the nature of the enzyme. It is transformed into dextrose by the action of dilute mineral acids. Glycogen is found in relatively large quantities in the liver and in smaller amounts in the muscles. It is found in traces in nearly all the tissues of the body and is therefore regarded as a primary or essential cell constituent. Some animals, as the Tænia and Ascaridæ and certain of the mollusca, as the pectin irradians, are very rich in glycogen. Many fungi contain significant quantities of glycogen.

The amount of glycogen in the organs of the body depends primarily upon the food. In starvation it may almost completely disappear. Feeding again causes anew the storage of glycogen and this retention occurs more rapidly when large quantities of carbohydrates are fed. The quantity of glycogen in the liver also depends upon the muscular activity of the body muscular work being performed preferably at the expense of carbohydrates of the body of which glycogen is the source. FRANK P. UNDERHILL.

Glycolysis.—By the term glycolysis is meant the process by which dextrose is transformed within the body to lower products. It is presumed that the action is of an enzyme nature and there is considerable evidence that many of the body tissues contain glycolytic enzymes. Cohnheim attempted to prove that the glycolytic power of muscles is dependent on an internal secretion of the pancreas. It was shown that if dextrose were incubated with muscle press juice or with pancreas press juice little of the dextrose disappeared. On the other hand, if fresh muscle and pancreas were minced together, the mixed press juice possessed marked glycolytic properties. Cohnheim demonstrated that this activation of the muscle was not dependent upon enzymes, since boiled extracts of the pancreas would behave in a like manner. Claus and Embden ascribed the glycolytic action of the mixed juices to bacterial contamination. This has been disputed by Cohnheim and a full confirmation of Cohnheim's work has been made by Hall. The glycolytic power of the blood is well known, having first been demonstrated by Claude Bernard. The products formed as a result of this glycolysis are not precisely known, although it has been asserted that alcohol may be produced.

Literature may be found in *Vernon:* Intracellular Enzymes, London, 1908.

FRANK P. UNDERHILL.

Glycoprotein.—A compound of the protein molecule with a substance or substances containing a carbohydrate group other than a nucleic acid. As instances of a glycoprotein may be given such substances as mucin and mucoids.

F. P. U.

Glycosolveol.—See *Antidiabetin*.

Glycuronates.—Glycuronic acid has not been found in the free state in the animal body. It occurs to a slight extent in normal urine as a conjugated acid, phenol—and probably also indoxyl—and skatoxyl glycuronic acid. Very large amounts of these conjugated glycuronates occur in the urine after the ingestion of various therapeutic agents and other substances as chloral hydrate, camphor, naphthol, borneol, turpentine, morphine, etc. The excretion of glycuronates may be markedly increased in severe disturbances of the respiration, in extreme dyspnea, in diabetes and by the direct introduction of large quantities of dextrose. According to the substance with which they are combined the glycuronates vary in behavior. Upon treatment with boiling mineral acids they split into glycuronic acid and the conjugated group. They are precipitated with basic lead acetate or with basic lead acetate and ammonia. Most of the conjugated glycuronates have a reducing action upon metallic oxides only after hydrolysis with acids. Certain of them, on the other hand, exert a reducing action on alkaline copper solutions and hence may cause errors in testing urine for sugar. Glycuronates of the glucoside type rotate the plane of polarized light to the left whereas free glycuronic acid gives dextro-rotation. Glycuronates of the ester type rotate the plane of polarized light to the right. FRANK P. UNDERHILL.

Glycyrrhiza.—LIQUORICE ROOT. The dried rhizomes and roots of *Glycyrrhiza glabra* L. Spanish liquorice) or of *G. glandulifera* Waldstein and Kittaibel (Russian liquorice (fam. *Leguminosæ*).

The liquorice plants are large perennial herbs, the different species either smooth or hairy. That first named grows principally in southern Europe, the second chiefly in southwestern Asia and adjacent Europe. Both are largely cultivated, the former

much more extensively. The plant sends down a very long root, which is nearly vertical, but may have several smaller branches. From the crown, just underneath the surface of the ground, a number of long horizontal rhizomes emanate. These, though frequently mixed with liquorice to increase the yield, are not nearly so good as the roots. They have, however, an important use for purposes of propagation.

Liquorice root, when first collected, is fleshy and juicy, and is largely employed in this condition. For commercial purposes the roots are thoroughly cleaned and dried rapidly to prevent moulding. The Russian variety has its outer bark removed.

There are great differences of opinion concerning the relative quality of the two varieties. The correct view probably is, that Spanish liquorice is sweeter, while Russian liquorice, when powdered, is lighter in color and of finer appearance. Russian liquorice is rather more inclined to be free from bitterness, provided care be taken to excise all black, knotty, decayed pieces. If these be allowed to remain, even to a slight extent, they impart a marked bitterness to the powder.

Description.—*Spanish Liquorice.*—In long, cylindrical pieces, from five to fifteen millimeters ($\frac{1}{5}$ to $\frac{3}{5}$ in.) thick, longitudinally wrinkled, externally grayish-brown to dark brown, warty; internally tawny-yellow; pliable, tough; fracture coarsely fibrous; bark rather thick; wood porous, but dense, in narrow wedges; medullary rays linear; taste sweet, very slightly acrid.

The underground stem, which is often present, has the same appearance, but contains a thin pith.

Russian Liquorice occurs in large, usually crooked pieces, often several feet in length and five centimeters (2 in.) in thickness, deprived of the outer bark, pale yellow without, internally of a lighter yellow than the Spanish and softer and of lower specific gravity, its cellular elements larger, its taste less sweet, and the wood frequently cleft. Any blackened, knotty, bitter portions should be removed before using.

Composition.—The most important principle is its peculiar sweet substance, *glycyrrhizin*, an amorphous, yellow, intensely sweet powder, soluble in hot water, but not in cold without the addition of an alkali. It is a glucoside, and may be resolved, by boiling with dilute hydrochloric acid, into an uncrystallizable sugar, and an amorphous, bitter substance, *glycyrrhetin*. It is said to be present in the root combined with calcium. Proportion about six per cent. There are also some sugar, three per cent. of asparagin, a variable amount of glycyramarin, a little resin and starch.

Action.—Liquorice has no physiological action beyond that of being slightly laxative and expectorant, chiefly through its stimulation of the mucous glands. It is, like other sugars and syrups, soothing to the mucous membrane of the fauces, and hence much employed in coughs by itself, or as a vehicle or ingredient of cough mixtures. Syrups of liquorice and the ammoniated glycyrrhizin have been extensively used as vehicles to cover the bitter taste of quinine, which they do in an imperfect manner. The ammoniated glycyrrhizin may be rubbed up with the quinine in powder, or the quinine may be mixed with a syrup of liquorice at the instant of taking.

Administration.—Several preparations are official. Fluid extract (*Extractum Glycyrrhizæ Fluidum*, U. S. P.), in which the liquorice is exhausted with diluted alcohol and ammonia, the latter to make the active principle more soluble. The pure extract (*Extractum Glycyrrhizæ Purum*, U. S. P., so called to distinguish it from the *Extractum Glycyrrhizæ*, or crude Italian stick liquorice), in which the drug is exhausted with water and ammonia, and the percolate evaporated to a semi-solid consistence. It is useful for pill masses and as a vehicle; it is also an ingredient in the compound mixture of liquorice (*Mistura Glycyrrhizæ Composita*, U. S. P.), or old Brown Mixture, in which paregoric and wine of antimony are the active ingredients. *Glycyrrhizinum Ammoniatum*, U. S. P. (ammoniated glycyrrhizin, mentioned above), is prepared by extracting the liquorice with ammoniated water, precipitating the sweet principle with sulphuric acid, washing, redissolving in ammonia and water, precipitating and dissolving again, until it is sufficiently pure. It is in dark brownish-red, shining, brittle scales, of a very sweet, liquorice-like taste, and no odor, soluble in water and alcohol. Compound liquorice powder (*Pulvis Glycyrrhizæ Compositus*) is, properly speaking, a preparation of senna. Besides these, should be mentioned the commercial "stick," or "black liquorice," formerly imported on a large scale from many of the countries and islands of the Mediterranean, now chiefly manufactured in this country. It is mainly used by children as a confection, but is also in extensive demand for coughs, colds, and sore throats. H. H. Rusby.

Gmelin, Johann Friedrich.—A name made famous by the writings of its possessor on chemistry, materia medica, pharmacy, and zoology. Born at Tübingen, August 8, 1748. As early as in the year 1775 Gmelin was chosen Professor in Ordinary of Philosophy at the University of Goettingen, and five years later he was made Professor Extraordinary of Medicine at the same university. He died at Goettingen, November 1, 1804.

Of Gmelin's numerous published writings that which brought him the greatest amount of glory is unquestionably his *History of Chemistry*, published in Goettingen, in 1797–1799, in 3 volumes. Another one of his famous works is his *General History of Poisons*, published at Leipzig and Nüremberg in 1776 and 1777, in 3 parts.

From the account published in the 1911 edition of the *Encyclopædia Britannica* it appears that Leopold Gmelin (1788–1853), a son of Johann F., also attained a great reputation as a chemist. In 1822 he discovered potassium ferricyanide. His "Handbuch der Chemie" was a most important work in its day.

A. H. B.

Gnats.—A rather indefinite term used to designate various small Diptera, not all of which bite. Mosquitos (*Culicidæ*) and midges (*Chironomidæ*), as well as sand-flies (*Simulidæ*) are often called gnats. See *Insects, Parasitic.* A. S. P.

Gnathostoma.—A genus of nematode worms in which the whole or the anterior end of the body is covered with minute spines. Several species are found in vertebrates; *G. siamense* has been known to form nodules beneath the skin in man. See *Nematoda.* A. S. P.

Gnathostomidæ.—A family of nematode worms. Only the anterior part of the body is covered with ramified spines. These animals live in the stomachs of vertebrates, especially mammals. *Gnathostoma* is the only genus. See *Nematoda.* A. S. P.

Godbold Mineral Wells.—Post-office.—Summit, Pike County, Mississippi. Hotels and boarding-houses in Summit. The hotel at the Wells is a large fire-proof building, located in a beautiful oak grove.

Access.—Via Illinois Central Railroad to Summit, one and a quarter miles from the Wells. An automobile road connects the two points. This well-

known chalybeate well is located in the suburbs of Summit, a village 108 miles northwest of New Orleans and 75 miles south of Jackson. The location is 420 feet above tide-water. The well has a depth of eighteen feet and a diameter of four feet. The supply of water is unlimited. The following analysis was made by J. H. Laster, chemist, of New Orleans:

One United States Gallon Contains:

Solids.	Grains.
Iron protochloride	11.42
Calcium sulphate	Trace
Sodium chloride	1.73
Calcium carbonate	Trace.
Silica	Trace.
Loss	.84
Total	13.99

The water is said to possess much value in the treatment of diarrhea and dysentery and in disorders of the stomach, liver and kidneys. It is used also in malaria, diabetes, rheumatism, and bladder troubles. It is bottled and sold, but many persons visit the well in person for the purpose of drinking its waters. The water is almost a pure chalybeate, the remaining ingredients being practically inert.

The Dixie Club has purchased the Godbold Wells property and has secured large shooting and fishing privileges. The aim of the Club is to make the resort a national headquarters for sportsmen and their families who are seeking health and recreation at any season of the year. Emma E. Walker.

Goerbersdorf.—This place is mentioned chiefly because it is the locality in which the renowned Brehmer Sanatorium for pulmonary tuberculosis—the oldest in existence, founded in 1854—is situated. The village of Goerbersdorf is located in the Southeastern part of Germany, in the province of Silesia, at an altitude of 1,840 feet. It is in the valley of the Steine, which runs from northwest to southeast, and is sheltered by densely wooded heights. The climate is not unlike that of the Adirondacks, for example, its main features consisting of "atmospheric purity, freedom from dust, dryness of soil, shelter against strong wind, and abundant sunshine." Its altitude is not sufficient to give it the character of an Alpine climate, though in a general sense it is a mountain climate. The season is an all-the-year-round one.

Here, sixty years ago, Brehmer founded his famous sanatorium, the parent of all the others. Begun in a small way, it now consists of large and handsome buildings with several detached villas, surrounded by very extensive grounds. Meeting with much opposition at first, Brehmer, before he died in 1889, had the satisfaction of seeing his method adopted more or less closely in all systematic attempts to cure pulmonary tuberculosis; other sanatoria established on the principles laid down by him; and more favorable results than had ever before been obtained in the treatment of the disease. To-day the Brehmer hygienic-dietetic treatment, with perhaps some modifications, is the best we have, when weighed by results, although the form and methods of the construction of sanatoria have much changed since Brehmer's day.

Brehmer's theory of the underlying cause of phthisis was a disproportion between the heart and lungs, the latter relatively voluminous, the former small, with thin, flabby, feeble walls. Consequently he considered that the most important object in the treatment was to strengthen the heart, and methodic hill-climbing the best means for obtaining this result. For this purpose, in the park of about 300 acres surrounding the sanatorium, he constructed over nine miles of footpaths of gentle ascent, with frequent benches and pavilions for resting. Measured walks of measured steepness constituted at that time a fundamental principle of his treatment, and only the febrile cases and those with some contraindicating complication were exempt. This plan of graduated exercise was not unlike that instituted by Paterson at Frimley many years later, though based upon quite a different theory, namely, that of autoinoculation. The other sanatoria have modified this plan, and place the emphasis upon the *Ruheluft-Kur*, rest in the open air. This method is followed, to be sure, at Goerbersdorf, but not to the extent that it is at Falkenstein and Hohenhonnef. At these latter it is the striking feature of the treatment.

The sanatorium building, of a plan now largely obsolete, is a large gothic structure of brick, of very imposing appearance, in the midst of a beautiful garden; and besides the old and the new *Kurhaus* there are three annexes or villas. The internal arrangements are very extensive, consisting of a winter garden, conversation and reading rooms, large dining halls, various reception rooms, an imposing gothic staircase, and bedchambers hygienically arranged. One notices various suggestive maxims painted on the walls, like the following: "Wolle nur eins, und das wolle von Herzen" (Desire but one thing and that with all the heart). "Die lohnendste Arbeit für einen Kranke ist: gesund zu werden" (The labor which best repays a sick man is to get well).

Besides the sanatorium proper, there are two detached buildings of plainer construction, where patients are received at a reduced price. There is also a chemical and bacterological laboratory a meteorological observatory, and a medical library. The clientage comes from Germany, Russia, Hungary, Poland; and I found two patients from America. The supervision of the patient's life is most exact and continuous; every two weeks he is examined anew by the physician in charge, and is always under the observation of one or another of the physicians, all of whom, except the director, take their meals with the patients. Each is individualized in his treatment. As an illustration of the painstaking care, I noticed in the little reading library certain starred books, and on inquiry I found that they were of a rather exciting nature and were forbidden to those of nervous temperament as likely to produce a rise of temperature or some other unfavorable symptom. There are five meals a day, reinforced by milk. Kefir is prepared on the premises in large quantities and is much used, especially in gastro-intestinal troubles and in conjunction with alcoholic drinks for night sweats. Most of the patients use wine or beer. In fever milk is the principal diet, and as much as three liters in twenty-four hours is given a patient.

Hydrotherapeutics, as in the other sanatoria, is an important adjunct of the treatment in the form of simple bathing with acidulated water, the wet pack with massage, and cold douches. I was interested in watching the method of giving the latter. In a room adjoining the douche sits a physician at a table, with a watch provided with a second hand, and with the names of those for whom the bath is prescribed. The attendant informs the physician through a speaking tube when the patient is ready, and the doctor turns on the water (which he alone manipulates) for the specified number of seconds, as indicated in his list. When the douching is completed, the attendant throws a blanket about the patient and rubs him down. Only the stronger and convalescent patients are allowed this douche.

The sputum is deposited in shallow cuspidors containing sawdust, scattered about the building. Each patient also has a Dettweiler pocket spit-cup. The sputum is destroyed by burning.

A few minutes' walk from the Brehmer establishment brings one to the late Dr. Römpler's sanatorium, which is also extensive, accommodating about one hundred patients. Although not so imposing as Brehmer's, it is equally comfortable and complete,

and, on account of the lighter character of the architecture, gives one a very pleasing and cheerful impression. In common with the other sanatoria, it possesses a fine winter garden, which is practically a great conservatory affording an extensive and beautiful view even to the horizon, and is the favorite lounging place for the inmates when the weather forbids outdoor life. The "Liegehalle" is in the second-story balcony with a glass roof, which seemed to me preferable to those on the ground floor. The extensive park is laid out with pleasant paths of varying grades (some protected) extending up to the richly wooded mountainside, with seats, terraces, and pavilions, which afford comfortable and picturesque resting places. The method of treatment is similar to that of the larger establishment; it comprises abundant alimentation, outdoor air (rest in the reclining chairs and walking in the paths of gentle ascent) and hydrotherapeutics.

Fig. 2814.—Brehmer's Sanatorium at Goerbersdorf.

Dr. Römpler thus well summed up the conditions of cure: "Upon the ability of the organism to *resist* depends finally the possibility of cure. To increase this power of resistance through gradual blunting of the susceptibility to irritation (hardening); through the improvement of the nutrition and quality of the blood; and, finally, through the avoidance of hurtful influences and through instruction and training for future guidance, is the principal problem of the phthisiotherapeutist."

The third sanatorium at Goerbersdorf is that of Dr. Weicker, which is a small one, and, as Dr. Weicker says, on the plan of a home rather than on that of a large institution, he and his wife living in the institution with his patients; and the method is essentially that of the others. It was originally founded by the Gräfin Pückler, under whose name it still stands. Dr. Weicker also has charge of a people's large sanatorium in Goerbersdorf, consisting of seven villas, which received 256 persons during the year 1896. It was established for working people who are members of the so-called insurance society for the disabled and aged; the expense being defrayed by the society, which allows each member a certain sum. The insurance societies of Germany of this nature are finding it to their interest to send their consumptive members to such an institution and have a certain proportion of them returned to their usual avocation, rather than support them indefinitely as invalids. Of 185 persons who were dismissed in 1896, 70.3 per cent. were capable of resuming their work; and for the three years from 1894 to 1896 inclusive, of those communicated with who were dismissed in these respective years as capable of resuming their work, 60, 71, and 89 per cent. respectively, still remained so at the beginning of 1897; so that from an economic point of view this plan of people's sanatoria is a profitable venture for the insurance societies.

Goerbersdorf is reached either via Breslau and Friedland, or from the station of Dittersbach on the Silesian Mountain railway. Either from Friedland or Dittersbach one has to ride four or five miles to the sanatoria. As to the results obtained at Brehmer's sanatorium, of 75,032 patients treated from 1876 to 1886, 26.6 per cent. were reported "cured and almost cured," of the first, second, and third stages of the disease collectively. Edward O. Otis.

Goiter.—See *Thyroid Glands.*

Goiter, Exophthalmic.—*Synonyms:* Parry's disease, Graves' disease, Basedow's disease, Struma exophthalmica, Hyperthyroidism.

Historical.—The disease generally recognized as exophthalmic goiter was described by Parry in 1825, by Graves in 1835, and by von Basedow in 1840. Parry even suggested that the thyroid might cause the cardiac disturbances. Later, after Claude Bernard's experimental work became known, the symptoms were ascribed to a neurosis of the sympathetic nervous system, but Gull in 1873 traced the origin of cretinism to the thyroid, and Ord in 1877 published his article

on myxedema. Then Kocher, in 1883, showed the results of total extirpation of the thyroid in human subjects, and about 1890 Murray and others introduced thyroid feeding. Shortly afterward, chiefly through Kocher's efforts, the beneficial effects of partial thyroidectomy in cases of exophthalmic goiter seemed to demonstrate that at least the immediate cause of the disease was to be ascribed to excessive functional activity of the gland. At first, and for a long time, it was thought that the symptoms must necessarily include exophthalmos, goiter, tachycardia, and the characteristic tremor in the extended fingers. Gradually, however, it has become apparent that neither exophthalmos nor goiter is a necessary accompaniment, of a greater than normal thyroid activity and to designate this condition the term "hyperthyroidism" has been introduced. The symptoms supposed to indicate the opposite disorder or deficient functional activity are much less definite, and are grouped under the term hypothyroidism.

Introductory.—Clinically, it seems that both conditions, hypothyroidism and hyperthyroidism, can coexist in the same individual, or that one may be followed by the other, and hence great confusion exists as to the significance of the almost innumerable symptoms presented by the subjects of thyroid disease.

The acquired diseases of the thyroid are usually enumerated as: (1) Goiter, and under this heading are grouped the simple, solid, cystic, and colloid goiters; endemic goiter is sometimes mentioned separately, but does not differ clinically from other goiters (2) Myxedema. (3) Exophthalmic goiter. (4) Cancer. There must now be added: (5) Hypothyroidism and (6) Hyperthyroidism, or abnormal conditions which there is good reason to believe are dependant to a greater or lesser degree upon deficient or excessive functioning of the gland.

The little which is known of these alterations from normal physiology has been learned from the study of the more extreme functional disturbances represented in myxedema and exophthalmic goiter. The common usage of the word hypothyroidism suggests or implies an incipient condition without structural change in the thyroid which may develop into a much more serious or functional and structural disease of the organ. Myxedema is thus ordinarily regarded as the terminal stage of a process or disease which runs a somewhat ill-defined course, but which nevertheless should be recognized early. The relationship between hyperthyroidism and exophthalmic goiter seems, however, to be less clearly understood, although there is a general agreement that the terms are not strictly synonymous. To facilitate the recognition of the extremely variable manifestations of abnormal thyroid function, and to aid in their interpretation so far as present knowledge permits, it is proposed to trace out step by step what may be called the natural history of thyroid disease in general, and thus obtain some conception of the apparent sequence of events and their significance. Cancer of the thyroid will be omitted from the discussion, as it seems to be a disease of the gland apart from the others. It is often accompanied by indications of hyperthyroidism or of active functioning in the diseased cells, and presents certain peculiarities which differ from cancer of other glands, but it seems to have nothing in common with the remaining acquired thyroid diseases.

That these may give signs which show totally different forms or degrees of function at different periods of time in the same individual is a matter of common observation. It is also well known that any "simple" goiter may develop into any of the typical thyroid diseases.

Course of Thyroid Disease.—The term "simple" goiter usually means a simple hypertrophy of the thyroid, or a multiplication of all the glandular elements without any discoverable alteration in structure other than increase in size. This simple goiter, or more exactly simple hypertrophy, always takes place to a greater or lesser degree before the development of the degenerative changes which mark the formation and development of the fibrous, cystic, or other true goiters or localized diseases of the thyroid.

In the next place, myxedema, which is generally regarded as originating in an atrophy and not in an hypertrophy of the gland, is much more common in patients with long-standing and badly degenerated goiters than in those who give no history of thyroid enlargement. Hence, a primary atrophy of the gland seems the exception rather than the rule. That is, at least some degree of thyroid hypertrophy appears to be the regular or most frequent beginning of what may later prove to be a true myxedema.

Similarly, typical exophthalmic goiter may appear without any noticeable increase in size of the gland, but such an occurrence is exceptional. It is far more common for the disease to occur after there has existed some degree of thyroid enlargement, and generally for a considerable period. Moreover, no simple or degenerated goiter seems exempt from the possibility at one time or another of showing the symptoms which are characteristic of Graves' disease, and hence it is reasonable to regard simple hypertrophy of the thyroid as the most common or "regular" first symptom or first stage in all of the acquired thyroid diseases.

Coincident with, or following, the appearance of the hypertrophy there commonly occur symptoms of a subjective more than objective nature, which are now regarded as expressing deficient function of the thyroid, or hypothyroidism. "Simple" goiter occurs at any age and under innumerable conditions and circumstances, but is most frequent at certain transition periods of life and during or after physiological processes which require much expenditure of energy. Its appearance in family or related groups of individuals is often noted and there can be little doubt that the peculiarity follows the Mendelian laws of heredity.

The True or Degenerated Goiters.—From these first and second stages, represented by thyroid enlargement and hypothyroidism, the disturbance may subside or advance in one of three directions. If toward goiter, or the degenerative changes in the gland which are characterized by alterations not only in the size but in the outline and consistency of the organ without other marked objective symptoms, these changes gradually make their appearance or develop quite rapidly and sometimes suddenly. The conditions or circumstances which precede or attend the local alterations in the gland seem to be in general the same as those present during the primary stage of simple hypertrophy; and just before the increase in size or in density occurs, some evidences of hypothyroidism may be noted, although the opposite or hyperthyroid signs appear to be more frequent, possibly because they are more easily detected.

The narration of case histories is objectionable, but is the best way of demonstrating this series of events.

Case I.—(Simple goiter of young women.) Miss J. F., age eighteen, was first seen January 2, 1908. She had become alarmed at the appearance of what her physician called "goiter." Tall, poor muscular development, thin neck, and enlargement of the thyroid to about triple the normal size. Skin pallid. No complaints except lassitude, weakness, anorexia, some constipation, and wakefulness rather than insomnia (hypothyroidism). Pulse 72, respiration 18, temperature 980, blood pressure 105, hemoglobin 90 per cent. Urine negative, menstruation regular though scanty, no discoverable abnormality other than the thyroid enlargement which in outline and consistence was that of a simple hypertrophy. There was a history of rapid growth at the age of sixteen, followed by the usual entrance into strenuous social activities of the well to do, with late hours and insufficient sleep. Advised a hygienic and simple life, with nine hours sleep each night and a small amount of thyroid feeding, to "help out" the supposedly fatigued gland.

May 16, 1910. Thyroid enlargement has disappeared. No discoverable abnormality.

February 26, 1912. Returns with a history of several months of strenuous social activity and complains of fatigue after the least exertion, and a small cyst about one inch in diameter in the right lobe of an otherwise imperceptible thyroid (hypothyroidism). This was discovered a few days previously after a night at a ball. No other abnormalities. Advised rest and hygiene and thyroid feeding as before.

March 15, 1913. Cyst smaller and softer, and apparently in process of disappearance. General health excellent.

Case II.—(Simple goiter followed by exophthalmic goiter.) Miss E. S., age fifty-three. First noted a goiter about thirty-five years ago, after a year of hard study and too little sleep. This was at first soft and symmetrical, but gradually became firmer and more uneven in outline. About six years ago, after the death of her parents and much financial anxiety, she began to be nervous and have palpitation. This was cured by rest and some medication administered in drops (potassium iodide?), but she remained weak (hypothyroidism). A year ago she was forced to move from her former home, and soon afterward noted a recurrence of the tremulousness and cardiac distress. She was unable to rest (hyperthyroidism), and some weeks later detected a peculiar stare in the eyes (exophthalmic goiter).

November, 1909, first seen, and presented the signs of mild but typical exophthalmic goiter with a large thyroid containing many cysts and much fibrous tissue. The exophthalmos was slight. Pulse 110–120. Blood pressure 140–150. She was given antithyroid serum for several weeks, and at the end of six months recovered completely, except that the goiter remained unchanged.

June, 1913. Goiter slightly increased in size. The pulse was 80 and irregular, though there appeared to be no gross lesion of the heart. The blood pressure varied from 160–180. There was no consciousness of any illness or disability.

After the goiter has become apparent, it may persist indefinitely unchanged or gradually shrink, or enlarge and then may cause pressure chiefly in the trachea. More frequently it is accompanied for longer or shorter periods by signs of hypo- or hyperthyroidism and these advance or recede like the purely functional diseases which represent the other two directions of the progress of the distubance after simple hypetrophy.

Hypothyroidism and Myxedema—After the development of simple hypertrophy with its attendant or subsequent hypothyroidism the disturbance may advance toward and into myxedema. The usual text-book description for this condition is of a chronic disease of middle life or later, which begins insidiously with atrophy and not with hypertrophy of the thyroid. But it cannot be disputed that the disorder frequently occurs in persons who have possessed a more or less quiescent goiter for months or years, and that after death the characteristic changes in the thyroid vesicles are the same in the goitrous and the atrophied glands. The only difference is in the amount of functionless structure. The so-called typical or idiopathic myxedema which begins after middle life with a primary atrophy of the thyroid is a rare disease in my experience, while the myxedematoid conditions which develop in long-standing goiters are very common and symptomatically the same. There is one noteworthy difference, however; the myxedema which occurs with a goiter is generally much more easily relieved than the disease which is accompanied by no thyroid enlargement. Indeed, typical myxedema, or that which follows primary atrophy of the gland, seems to be a very serious if not an irremediable condition. It is not the easily cured disease ordinarily described.

Hyperthyroidism and Exophthalmic Goiter.—These terms should not be used as though they were synonymous. The primary, or first, stage of simple hypertrophy and the next of hypothyroidism may directly and either rapidly and without detection of the hypo-stage, or gradually and with more noticeable signs of hypothyroidism, advance into the third period of the disease or that of hyperthyroidism. This, in turn, may be followed gradually or rapidly, though only in about twenty-five per cent. of the cases, by the fourth stage or that of exophthalmic goiter which, like myxedema, seems regularly or in its most usual form to be the termination of a more or less chronic process.

Case III.—(Simple hyperthyroidism.) Miss L. C., age twenty-eight. Her occupation as ladies' maid compelled her to pass the years of 1906 and 1907 with only a few hours sleep nightly and constant care of clothes during the day. In December, 1907, after an attack of grippe, her physician noted the goiter. In January, 1908, she was weak and tired, and had early morning wakefulness. In May, 1908, headache, insomnia, anorexia, and constipation, or signs of hypothyroidism, appeared. A competent observer said that at that time there was no tachycardia. In June she noticed dyspnea on exertion, palpitation of the heart and trembling. In July the headache had disappeared, but the goiter had become larger and the other signs of hyperthyroidism were unmistakable. There was no exophthalmos. She then had a pulse rate of 120–140, with the vasomotor and nervous phenomena characteristic of her condition. There was a considerable goiter much larger on the right than left side.

August 4, 1908. Under ether, the right or larger lobe and the isthmus were excised. There followed a severe reaction which subsided in the course of a week, and in September, 1908, she left the hospital apparently well, but still weak and with a perceptible left lobe of the thyroid, and on my advice went to her home in Sweden for eight months. In June, 1909, she returned in apparently perfect health and resumed work as a childrens' governess.

November, 1911. Appears with a dry cough, pulse 90–100, blood pressure 110, some insomnia, constipation, and weakness. These symptoms followed much fatigue in the course of her duties as a governess. A two weeks vacation' with a little thyroid feeding, was followed by a complete restoration to the normal. (Mixed hypo- and hyperthyroidism.)

January, 1913. A similar disturbance was relieved in the same way. This illustrates the course of an apparently perfect cure of hyperthyroidism by partial thyroidectomy.

Many cases remain for an indefinite period in the third, or hyperthyroid stage, and these often show alternations in symptoms; sometimes those of excessive activity of the gland predominated, and again those of deficient functionation. If recovery is to take place, however, the evidences of hyperthyroidism gradually grow less and usually occur at longer intervals, during which the symptoms of hypothyroidism are more or less distinct, and may not cease until the goiter or last symptom disappears.

On the other hand, death may occur at any time after the beginning of the third or hyperthyroid stage, but it is much less common in this than the fourth stage or that of exophthalmic goiter. The fatal end may come rapidly from an acute intensification of all the symptoms, or gradually and after years with increasing signs of myxedema. But the immediate cause of death is then more frequently one of the complications which occur with a rising blood pressure; for the third stage, or that of chronic hyperthyroidism, if of long duration, sooner or later shows an increase in arterial tension, and this is accompanied by cardiac and nephritic and other degenerative lesions.

Case IV.—(Acute toxemic thyroidism following simple goiter.) Miss M. R., age eighteen, was a school athlete and great basketball player. After the first year of these activities, at the age of seventeen, a small soft goiter was noted. She played tennis during the next summer without discomfort and with much energy, but tired easily and was constipated and had many headaches (hypothyroidism). In the fall she entered college and attempted gymnasium athletics, but was forced to stop because of the constantly rapid heart action (hyperthyroidism). At this time the headaches ceased and the constipation disappeared, and she was "nervous" and had some insomnia.

November, 1905. After rest, enforced by these conditions, the pulse slowly came down to 100 or 110, and she considered herself well, but seems to have had a constant slight hyperthyroidism and a small goiter.

May 4, 1906, she attended a class banquet and the following day developed an acute gastroenteritis. On May 6, the pulse began to show an alarming increase in rapidity, reaching 200 or more to the minute. There was severe headache, extreme restlessness and a temperature of 101° to 102°. The goiter was dense and of small size, and there was marked pulsation in the cervical vessels. The headache deepened into stupor. The temperature increased, and death followed without the appearance of any exophthalmos.

Case V.—(Chronic hyperthyroidism and death from nephritis.) J. G., age fifty-six. Had worked at his business as a banker very hard and for many years with no vacations. During 1899 he had many headaches and was easily fatigued (hypothyroidism). He then took a month's rest, but after resuming work began to be troubled with breathlessness, palpitation, and a small goiter was detected (hyperthyroidism). He was then treated for Graves' disease though there was no exophthalmos. During the next six years there were periods of headache, constipation, pallor, and asthenia after resting, which alternated with nervousness, palpitation, dyspnea, and insomnia after times of business activity. These were apparently periods of alternating hypo- and hyperthyroidism. In 1906 there was considerable pigmentation and a dry skin. No exophthalmos, but a peculiar puffiness about the eyelids. A small, firm goiter. Pulse 100–110. Blood pressure 150–160. In 1907 the only change was an increase in blood pressure to 160 or 170. Urine negative. In April, 1908, a partial thyroidectomy was performed in Europe, with some relief of the nervousness and tachycardia, but with no improvement in the strength. In June, 1908, the blood pressure was 180. Urine negative. In January, 1909, there were still slight evidences of hyperthyroidism and the blood pressure was about the same, but the urine showed casts and traces of albumin. The blood pressure varied between 200 and 230. There was no exophthalmos. During the following six months there was a gradual loss of strength and uremia finally developed, and after a few days terminated fatally.

Though regularly produced by hyperthyroidism, exophthalmos is not by any means a constant result of it. In my experience it is encountered in not more than twenty-five per cent. of the total number of individuals who give signs generally accepted as those indicating a greater than normal activity of the gland. Hence the necessity of the term hyperthyroidism; as ordinarily used it seems to imply an incipient condition which may result in one of a more serious nature. Exophthalmos appears after and not before the other symptoms, and when it occurs it shows the incidence of the fourth stage, or that of typical exophthalmic goiter. This fourth stage of the disease is marked by a gradual and generally intermittent development of its distinguishing symptom. After this occurrence, the hope for recovery is distinctly less than before, and the probabilities of the development of complications are greatly increased. If the exophthalmos is only moderate and of recent development, a restoration to a completely normal state may take place. But the more pronounced this symptom and the longer it has existed the less is the hope of its disappearance.

If recovery is to follow, the exophthalmos subsides first only when it has been slight or intermittent or of recent occurrence; next there is the same retrogression through the stage of hyperthyroidism and the mixed stage of hyper- and hypothyroidism. Then follows a gradual predominance of hypothyroidism and possibly some enlargement and softening of the goiter, until after months or years this last symptom, the goiter, disappears. More frequently, at least some traces of the exophthalmos persist and even outlast all other signs, including the enlargement of the thyroid. But if this abnormality persists long enough there will almost certainly follow a rising blood pressure and its attendant dangers. A glycosuria may appear, and is a dangerous complication. A psychosis has occurred often enough among my cases to receive mention as a not infrequent complication, especially of the fourth stage.

Case VI.—(Simple goiter, hypothyroidism, hyperthyroidism, exophthalmic goiter.) Mrs. H. H., age twenty-eight, has always been nervous and has suffered from childhood with frequent headaches and bilious attacks. During the latter months of her first and only pregnancy six years ago, she apparently had some toxemia with albuminuria, but bore her child without accident at full term. In 1909, this child had anterior poliomyelitis, and the mother took care of her alone night and day, and suffered great fatigue and anxiety for many months. When the child began to recover in December, 1910, a goiter was noted in the mother, who complained of weakness, constipation, and much headache (hypothyroidism). In February, 1911, the mother had another period of anxiety, and the goiter enlarged and palpitation and dyspnea on exertion became troublesome. About this time the headaches subsided and insomnia was more or less constant (hyperthyroidism).

May 11, 1911. Typical hyperthyroidism. Large firm goiter. Tremor. Moist and flushed skin. No exophthalmos. Pulse 120–130. Blood pressure 130. The treatment consisted of injections of antithyroid serum, and a carefully regulated and hygienic mode of life.

May, 1912. Apparently a perfect cure, with the exception of a small, soft goiter.

June, 1912. A month was passed in very strenuous social experiences with dancing and late hours.

July 2, 1912. Appears again with typical hyperthyroidism. No exophthalmos. Antithyroid serum was tried, but no benefit followed.

July 15, 1912. During the past weeks her child has been ill, and again caused her much anxiety, and now exophthalmos is distinct after exertion or excitement. While quiet in bed it is not apparent.

July 25, 1912. The condition seems worse. Pulse 130–140. Goiter firmer. Expansile pulsation in cervical vessels and exophthalmos seems constant and more pronounced.

July 31, 1912. Novocaine adrenalin anesthesia. Right superior thyroid vessels tied and cut, and tip of right lobe excised. Left inferior artery ligated and not cut.

August 7, 1912. Novocaine-adrenalin anesthesia. Left superior vessels cut and tip of left lobe excised. Right inferior artery ligated.

August 25, 1912. Considerable reaction followed these slight operations, but it gradually subsided.

October, 1912. Pulse 110–120. Exophthalmos somewhat improved. Goiter soft. Blood pressure 120. Complains only of weakness and of growing fat. Has gained 15 pounds.

May, 1913. Pulse still irritable, but when patient is at rest pulse is 80–90. Exophthalmos only perceptible after exertion. (Mixed hypo- and hyperthyroidism.)

October, 1914. No trace of any abnormality except a slightly enlarged left thyroid lobe.

As in the previous stage, death may occur at any time and acutely in this fourth period, with an intensification of all symptoms, or slowly after the elapse of years. Under the latter conditions there is almost invariably a gradual rise in the arterial tension. With it there regularly occur degenerative lesions of the heart which supersede the regular signs of hyperthyroidism until these become unrecognizable. Their place is taken by a myxedematoid state, or one of hypothyroidism, and all that remains to recall or suggest the original difficulty is the exophthalmos. Though this termination is manifestly not typical exophthalmic goiter, it is the regular terminal, or fifth stage of the process which passes through the four preceding stages.

Case VII.—(Termination of chronic exophthalmic goiter.) Mrs. A. F., age fifty-two, was said to have developed exophthalmic goiter about fifteen years ago. She was first seen in November, 1907. There was very pronounced exophthalmos, an ivory-white pallor, much edema about the legs, a moderate-sized, hard goiter of uneven outline, enormously dilated cervical veins and very marked pulsation in the cervical vessels. Heart dilated, many abnormal sounds; apex in the anterior axillary line. Pulse extremely irregular and varying between 60 and 150. Blood pressure (systolic) 180–220. Urine contains a large amount of albumin and casts. This patient for the past six months had shown considerable mental deterioration, and required the constant care of two nurses. The mentality rapidly failed, and death took place apparently from uremia, in January, 1908.

Rarely, the disease takes another form and develops without any appreciable enlargement of the thyroid. The stage of goiter and hypothyroidism does not occur, and that of hyperthyroidism appears to develop more rapidly or even suddenly, and may or may not be accompanied by more or less pronounced exophthalmos. This course of events is exceptional, but when it takes place without enlargement of the thyroid, or with but slight enlargement and that after the appearance of the other symptoms, the disease is generally of unusual severity, as is the case with acute toxemic thyroidism, and it is exceptionally difficult to relieve by methods which are successful with hyperthyroidism in the presence of goiter. In other words, a condition in which there is great enlargement of the gland with signs of its

excessive activity seems less to be feared than a similar condition with little or no enlargement of the gland, and the same is true of the typical myxedema in which no perceptible goiter has occurred.

All the acquired diseases of the thyroid, with the exception of cancer, thus seem to begin with a simple hypertrophy which is apparently physiological and not pathological, and is accompanied by more or less distinct signs of hypothyroidism. If thyroid disease is to follow, it advances from this point to the different forms of simple goiter; or through intensification of the signs of hypothyroidism with a decrease or increase in the size of the "goiter" into myxedema; or through a more or less rapid change of the signs of hypothyroidism into those of hyperthyroidism, to which the symptoms of exophthalmos finally, in the more severe cases, may be added. If exophthalmic goiter lasts long enough, a myxedematoid state follows. Any simple goiter which has existed perhaps for years without the accompaniment of disturbances in other organs, may give rise to hypo- or hyperthyroid symptoms and develop into myxedema or exophthalmic goiter.

Recovery from hyperthyroid conditions may take place from any stage except the last, or fifth, stage, and the prognosis seems better in the presence of goiter than when this symptom is absent. The prognosis is much worse after the development of exophthalmos than before, as over eighty-four per cent. of the deaths in hyperthyroid conditions in my experience have occurred in cases which have presented this symptom, and the more pronounced it is the worse the outlook both as regards disabling complications and the duration of life.

If recovery takes place, it is gradual and through a retracement of the steps which mark the advance in the disease. Restoration to health after the development of hyperthyroidism always passes through a period in which hypothyroid symptoms alternate with those of hyperthyroidism until they gradually supersede and entirely displace the latter. After the development of exophthalmic goiter this course toward recovery through an alternating hypo- and hyperthyroidism is often accompanied by the persistence of the exophthalmos even after the goiter and every other abnormal sign has subsided. With this exception, the enlargement of the gland is the last of all the signs of thyroid disease to disappear.

Irregular Types of Exophthalmic Goiter.—The different manifestations which mark the different stages of functional thyroid disease, when it advances in the direction of overaction of the gland, explain many of the types of so-called irregular exophthalmic goiter.

(*a*) Probably the most numerous are those which present thyroid enlargement and more or less marked evidences of hyperthyroidism but no exophthalmos. Such cases belong in the group which has not advanced beyond the third stage, and may never go beyond it. If, with the hyperthyroidism, there are also signs of hypothyroidism, the disease may be alternating between the second and third stages, and be gradually receding, or if the blood pressure is above 140 or 150 millimeters of Hg, advancing into its myxedematoid termination. These cases often have had a quiescent goiter for long periods without other symptoms.

(*b*) Another considerable number show exophthalmos and pronounced signs of hyperthyroidism, but little or no goiter. These are truly irregular in that the absence of thyroid hypertrophy generally means a worse prognosis than the same symptoms with considerable enlargement of the gland. Partial thyroidectomy may slow the pulse rate and check or alleviate the nervous irritability, but it seldom cures this type of the disease. Many of these cases also seem to run a comparatively acute course and either die from toxemic hyperthyroidism or pass early into the terminal or myxedematoid fifth stage with its rising blood pressure and attendant complications.

(*c*) A small number of irregular cases may show exophthalmos with many peculiar nervous symptoms, but present very little or no tachycardia, which is generally accepted now as the most distinctive evidence of true hyperthyroidism. This type requires notice because radical operation or hemithyroidectomy generally is injurious.

(*d*) A small group of cases without any marked exophthalmos or goiter or without any easily recognized signs of the usual preliminary hypothyroidism or asthenia pass from comparatively good health within a few days into toxemic hyperthyroidism. In these the diagnosis cannot be made clinically unless some degree of thyroid enlargement is perceptible or unless at least Stellwag's sign of the "staring" eye is present.

(*e*) There are quite a number of patients who show some constant or intermittent signs of hyperthyroidism, usually of slight intensity, but in whom the results of treatment by checking the activity of the gland strongly suggest that the thyroid disease is secondary to other and more important abnormalities. The most conspicuous symptoms pertain to the central nervous system and are manifested in headaches, or nervous irritability, or a psychosis, or a mental and physical asthenia out of proportion to the state of apparently good nutrition. Less often there are pronounced valvular lesions in the heart, or occasionally there is an unexplainable constipation or diarrhea. Whenever the hyperthyroid symptoms are present, however, they advance or recede as in the more regular cases, and though much observation and study may be required the relative importance of the hyperthyroidism can generally be inferred and the treatment conservatively conducted.

In addition to these groups of irregular disturbances, in which the thyroid seems to participate symptomatically, there is sometimes described another under the designation of "Dysthyroidism." In my opinion this term should be restricted to cases which present an obvious enlargement of the gland limited to some particular portion of the organ and who complain of headaches or other symptoms not directly traceable to the thyroid and constant or intermittent disturbances having some of the characteristics of either hypo- or hyperthyroidism. If in these cases the complaints can be relieved or cured by extirpation of the diseased area in the thyroid, it is fair to assume that the abnormal tissue gave origin to some peculiar substance which differed from the normal thyroid product and so caused the symptoms. The localized disease seems to act like a retention cyst which occasionally allows its pathological contents to leak into the circulation. I have seen a few cases of this kind in which intermittent or remittent headache was the predominant complaint, and after removal of the cyst or tumor from the thyroid the pain has been sometimes, but not always or not permanently, cured. Three other cases in which symptoms like those of paroxysmal tachycardia were the most distressing, seem to have been more or less completely relieved by excision of the cystic or adenomatous area in the thyroid together with simultaneous ligation of its two superior vessels.

The irregular types of exophthalmic goiter can then be summarized in groups as follows:

(1) Cases in some stage of an increasing or decreasing process which normally or most frequently or regularly begins with simple goiter and is followed by hypo-, then by hyperthyroidism, then by exophthalmic goiter, and then by a myxedematoid state, and which may return to the normal in the reverse order from all but the last state.

(2) Cases which represent variations from this process in that they never pass beyond the stage of hyperthyroidism, except to enter directly into the

myxedematoid state. This group is really a division of Group 1.

(3) Cases of exophthalmic goiter in all particulars except that the symptoms supposed to be directly traceable to hyperthyroidism are slight or absent while exophthalmos or evidences of disturbance in the central nervous system are present.

(4) Cases in which evidences of hyperthyroidism are intermittent or slight, while symptoms referable to organs other than the thyroid are prominent only need mention, like the previous group, to make the thyroid prognosis guarded and the treatment conservative.

(5) Cases of so-called dysthyroidism which might properly be grouped in Class 4.

Symptoms of Hyperthyroidism (including those of exophthalmic goiter).—A great variety of conditions and circumstances have been described as attending or preceding the inception and the advance from one stage into the next of all types of thyroid disease. By "conditions" are meant biochemical processes of a physiological or pathological nature, and by "circumstances" matters pertaining to the environment which conceivably or demonstrably intensify these processes. When the history of each case is analyzed, the only influence which seems constant throughout all forms and all stages of these functional thyroid disturbances must be designated as fatigue. Its physiological effects upon different organs are to a large extent unknown, but there can be little doubt that it decreases the functional activity of one structure more than another in proportion to its intensity and the location of its maximum impact, and in the case of a gland like the thyroid, which experiments demonstrate to be closely related to the functions of many others, some balance seems to be impaired and there results first hypofunctionation and either atrophy immediately or hypertrophy, hypo-, then hyperfunctionation and atrophy later. The fatigue, in cases in which it may not be manifest, can generally be assumed if not proved to be the result of activity of concealed or unknown biological processes either in the thyroid or its more closely dependent or associated organs.

This introduction to symptomatology anticipates the discussion of physiology, but is helpful in the interpretation of the history of the course of events which arise in any stage of thyroid disease. The only common denominator to which can be reduced all the apparent causative agencies in these disturbances is fatigue, and conversely the one constant remedial agency is rest.

By abnormality of the thyroid is meant an hypertrophy of the gland, or any symptomless goiter, or any disturbance which may culminate in myxedema or exophthalmic goiter. During the inception of any thyroid abnormality, or during the intensification from one stage into the next of any hypo- or hyperthyroid symptoms, there is always a history which can be construed only as some unusual or excessive tax upon nutritional processes. A considerable amount of energy is expended, and this is ordinarily accompanied by more or less marked evidences of fatigue. An individual of the "nervous" type is placed in an environment which requires much mental alertness and generally a large amount of physical exertion. It may be a child in an uncongenial school, a trained nurse working on night duty, a teacher with a refractory class, a wife caring for a sick husband, or an athlete undergoing much competitive strain. Following these experiences, an enlargement of the thyroid occurs, and with it there is the lassitude of ordinary or physical fatigue. Its symptoms are now generally accepted as those of hypothyroidism, but only when in conjunction with them there is at least an appreciable hypertrophy of the gland. The evidences of this condition can then be enumerated as beginning with a history of some excessive expenditure of nervous or physical energy or both; later there are mental and muscular lassitude or asthenia, some headache, some insomnia or inability to sleep after midnight, defective functioning in the gastrointestinal tract with anorexia, fermentation and constipation, a subnormal temperature and a (systolic) blood pressure below 120 millimeters of Hg. There are, also, dryness and pallor of the skin, but no constant anemia. If the disturbance increases or progresses toward myxedema, there is usually a loss of hair and a slow intensification of these vague signs which, at least at the outset, are physiological rather than pathological.

If, on the other hand, the disturbance advances in the other direction or toward hyperthyroidism and its later stage of exophthalmic goiter, a distinct alteration in this picture takes place, but always under the same or analogous conditions and circumstances which attend the development of the preceding stages of the disease. The history is the same at each period of intensification of the disturbance, and can only be construed as that of fatigue of the thyroid and of the organs with which it seems most closely associated. Following this initial period of hypothyroidism at a longer or shorter interval the headaches and the feeling of lassitude disappear and are succeeded by nervous irritability. The subject shows quick and jerky movements and, at the same time, presents manifest muscular weakness of which there may or may not be consciousness usually in the form of dyspnea and cardiac palpitation on exertion. The wakefulness in the early morning hours of the initial hypothyroidism generally changes to an inability to obtain sleep before midnight or later, and is accompanied by a sensation of thumping heart. Many of the signs now generally accepted as those of hyperthyroidism can be traced to excessive activity in the sympathetic nervous system, and are usually enumerated as (1) any degree of tachycardia not otherwise explainable; (2) a moist rather than a dry skin which flushes at the least emotion; (3) nervous irritability; and (4) a mental and physical asthenia which is peculiar to all forms of thyroid disease. If (5) there is added to the preceding signs a perceptible enlargement of the thyroid (for the normal gland cannot be seen or felt) the diagnosis should be considered as positive.

There are many cases of hyperthyroidism, however, in which the history is not that of fatigue or of environmental conditions, which evidently force the expenditure of an excessive amount of energy. In these the disorder may begin insidiously during certain periods of life, such as mark the changes from childhood to youth or adolescence, or during a period of unusually rapid growth, or during pregnancy. It may first appear after some infectious disease, a traumatism, or fright, or other pronounced emotional disturbance, but under these conditions, from what is known of the physiology of the thyroid as will be stated later, it seems fair to assume that the ultimate cause of its overactivity is the same. The fatigue, however, is of a biological or chemical rather than physical nature. It originates from internal rather than external or environmental strains.

The history of the conditions and circumstances which precede and accompany the beginning of the process may show these variations in each stage of its advance, but they all seem reducible to the same common denominator. They all seem to demand an amount of work on the part of the thyroid which is apparently more than it is naturally capable of performing. Normally, or regularly, the gland first hypertrophies, then becomes fatigued and finally (if it does not atrophy) overacts and gives rise to the symptoms of hyperthyroidism, and later, but only in about twenty-five per cent. of the cases, to those of exophthalmic goiter.

The symptomatology of the latter condition is

unmistakable after it has developed, but should be recognized in the great majority of cases in the earlier stages and the advance prevented. Typical exophthalmic goiter has a much more serious prognosis than simple hyperthyroidism, as in my experience over eighty-four per cent. of the deaths from thyroid disease have occurred during this stage or period of the disturbance.

The protrusion of the eyes usually begins more or less slowly, and at first has the characteristic of a stare rather than prominence of the eyeball, and is then known as "Stellwag's sign." It is not a true exophthalmos but a retraction of the lids accompanied by an infrequent closure of them, which seems to be due in part to a decrease of the lacrymal secretion and in part to spasm of the muscles supplied by the third cranial or an "autonomic" nerve. Moebius' sign, or the inability to converge the axes of the eyes, and von Graefe's sign, or the retraction of the upper lid manifested by its inability to follow the eyeball in downward rotation, belong to the same phenomenon. Accompanying or following these peculiar disturbances there is generally some exophthalmos. The organ becomes more prominent than normally, and at the same time there is usually an increase in the more distinctive and characteristic signs of hyperthyroidism. For exophthalmos, though it regularly follows the disturbance and thus seems to be caused by it, as remarked before, occurs only in a minority of the cases of hyperthyroidism, and then often persists after all other signs of hyperthyroidism have disappeared. The vasomotor and nervous irritability, the exaggerated pulsation in the great cervical vessels and in the heart, the flushing and moisture of the skin, on the other hand, are more characteristic of overactivity on the part of the thyroid, and are usually intensified with exophthalmos of increasing severity. The protrusion of the eyes rarely may become so pronounced as to force the greatest diameter of the globe beyond the lids, thus allowing them to close behind it. Less rarely because of the protrusion the lids cannot completely close and the consequent loss of protection may result in inflammation and ulceration of the cornea and destruction of the eye.

The goiter, which is supposed to be one of the other characteristic signs of the disease, is extremely variable, but its vascularity and density are in general in direct proportion to the severity of the other symptoms. In long-standing cases, and in those which have developed after a simple goiter or hyperthyroidism of considerable duration, the degenerative changes which have already occurred in the gland may hide the little which can be learned from palpation. As a rule, however, the more acute and severe the disease, the less seems to be the proportion of the colloid to the other elements in the gland, and this peculiarity is apparent in its external examination. Not infrequently the enlargement of the thyroid is inconspicuous or absent, and under these conditions the prognosis seems generally to be worse than when a considerable goiter is present. The disease, when accompanied by a small or absent goiter, seems more difficult to cure. The tachycardia, which was mentioned first, in the enumeration of symptoms, and which originally was enumerated after the exophthalmos and goiter as the third in this triad of symptoms required to establish the diagnosis, may be merely an increased frequency of the heart beat without exaggeration in force, or the contractions may be enormously augmented in vigor in addition to being rapid. The abnormally violent cardiac action is very distressing, and is often felt as a pounding or throbbing, and is manifested by a noticeable precordial impulse which is sometimes so severe as to shake the bed on which the patient is lying. The nervous symptoms, which are most constant and characteristic, consist in a mental instability rather than alertness, in quick, jerky movements of the extremities, a constant restlessness or inability to remain quiet and a tremor or tremulousness in the extended fingers which is very similar to that noted in extreme physical fatigue. The muscular reflexes are regularly exaggerated. A few cases of exophthalmic goiter present symptoms which closely simulate disease of the medulla or spinal cord or peripheral nerves, and it is difficult to determine whether the hyperthyroid condition is a cause or merely a complication of the other disturbances which may be of a trophic, a motor, or sa ensory nature, or a combination of these. Those which I have observed occurred after the incidence of the thyroid disease, and if recovery took place these irregular nervous symptoms remained apparently unchanged.

As the signs of hyperthyroidism often occur in conjunction with hypothyroidism during the advance or recession of these disturbances from one stage to the next, and as it is important to recognize the disturbance at its beginning, the symptoms can best be studied in contrasting columns.

The Early Stages of

Hypothyroidism.	Hyperthyroidism.
1. Goiter of any size but soft.	1. Goiter firmer.
2. More common in women during transition periods of life.	2. The same.
Skin.	*Skin.*
1. Pallid and dry.	1. Moist and flushed.
2. Loss and dryness of hair.	2. Hair fine and oily.
3. Finger nails brittle.	3. Normal.
4. Subcutaneous fat abundant—increasing.	4. Normal or decreasing.
Alimentary Tract.	*Alimentary Tract.*
1. Mouth dry.	1. Abundant saliva and mucus.
2. Tongue pale or coated.	2. Normal.
3. Anorexia.	3. Appetite excessive.
4. Intestinal fermentation.	4. Digestion good.
5. Constipation.	5. Bowels move more than once daily.
Circulatory System.	*Circulatory System.*
1. Normal pulse rate.	1. Accelerated.
2. Blood pressure 110–115 mm. Hg.	2. From 120–130.
3. Blood count normal.	3. Inconclusive but may be lymphocytosis.
4. Slight anemia.	4. Hemoglobin normal.
5. Temperature slightly subnormal.	5. Slightly above normal.
Respiratory Tract.	*Respiratory Tract.*
1. Respiratory rate less than 20 per minute.	1. From 20–24.
Nervous System.	*Nervous System.*
1. Incapable of sustained effort.	1. Overactive and excitable.
2. Some headache.	2. None.
3. Insomnia after 2 or 3 A. M.	3. Insomnia before 2 or 3 A. M.
4. No tremor.	4. Tremor present.
Genito-urinary System.	*Genito-urinary System.*
1. Sexually apathetic.	1. Excitable.
2. Urine pale and specific gravity below 1020.	2. High colored and above 1020.

Musculature normal but incapable of sustained activity in all functional thyroid disease.

Later Stages of

Hypothyroidism.	Hyperthyroidism.
1. Goiter small and firm, or absent.	1. Goiter of any size.
2. Incidence same as in early stages.	2. Same.
Skin.	*Skin.*
1. Pallor, ivory white, dry and thick, flush on malar prominences, edema of ankles.	1. Pigmented, and moist only after exertion or excitement.
2. Hair dry and scanty.	2. Hair fine and moist.
3. Puffiness of eyelids.	3. Exophthalmos in twenty-five per cent. of the cases.

Alimentary Tract.	*Alimentary Tract.*
1. Mouth dry.	1. Slight salivation.
2. Tongue pale or coated.	2. Tongue normal.
3. Marked anorexia, intestinal fermentation, constipation.	3. Excessive appetite, normal digestion, bowels loose.
4. None.	4. Thirst marked.
Circulatory System.	*Circulatory System.*
1. Slow pulse.	1. Tachycardia.
2. Blood pressure below 110.	2. Above 130.
3. Blood shows some anemia.	3. Some lymphocytosis.
4. Temperature 96–97.	4. Above 98.5 to 100 or more.
Respiratory Tract.	*Respiratory Tract.*
1. Respiratory rate below 18.	1. Above 22.
2. Some cough, which may be very pronounced.	2. None.
Nervous System.	*Nervous System.*
1. Mentally dull and apathetic.	1. Excitable and unstable.
2. Much headache.	2. None.
3. Insomnia variable.	3. Insomnia constantly.

The musculature shows an increasing inability to withstand fatigue.

Pathology of Hyperthyroidism or Exophthalmic Goiter.—The most constant and characteristic changes in this condition are to be found in the thyroid gland. In the earlier stages of the disturbance there is congestion with increased secretion of colloid in the alveoli. The colloid does not stain as deeply with eosin as the colloid in normal glands. A little later, or as the disturbance increases, so does the hyperemia and the pale staining colloid. At the same time a hyperplasia of the cells takes place, and the alveoli, instead of being rounded, show papillary projections into their interior which consists of the basement membrane and on its surface the proliferating epithelium. In fatal or toxemic cases the colloid then decreases in amount and the alveoli become filled with epithelial cells in various stages of disintegration. A cross-section of such a gland appears solid and of a yellowish color. If the disturbance decreases or does not reach this degree of severity but continues longer, atrophy and fibrosis appear with hyaline changes in the stroma, sclerosis of vessels, hemorrhages, and cyst formation. The cases which survive the stage of exophthalmic goiter and continue with some of these symptoms but with a preponderance of others which are characteristic of myxedema show in the thyroid the small alveoli of the atrophic gland surrounded by much fibrous tissue, and in adjoining areas the papillomatous projections of epithelium on its basement membrane into other alveoli as in the gland of typical hyperthyroidism.

The whole histological picture of the gland in the hyperthyroid condition is in short that of increased functional activity, and the more severe the clinical symptoms the greater is the multiplication of the epithelial cells which appear to desquamate into the alveoli and thus alter the character of the colloid until in the severest types of the disease the colloid may entirely disappear. In other words, the histological evidence is all in favor of a more complex disturbance than a simple over-production of the normal thyroid secretion. It is undoubtedly increased in quantity in the earlier or milder stages of the disease, but as it advances not only the total amount of thyroid secretion may decrease but its composition may change and that too with only an intensification of the same clinical manifestations. Chemical and biological studies show that the function of the gland is performed by some iodized protein of which several have been isolated but none as yet identified as the sole active ingredient. These all produce some effect which in general is in direct proportion to their iodine content. The normal thyroid has been demonstrated to contain 0.3 milligrams of iodine per gramme of fresh gland substance, while the pathological thyroid of Graves' disease or of hyperthyroidism contains noticeably less and the smaller the amount of iodine per gramme of gland substance the more severe seem to be the symptoms.

Of the other ductless glands which recent investigations show must have more or less connection with the hyperthyroid disturbance, the thymus seems most important. It has been frequently found present or enlarged, especially in the fatalities which may follow partial thyroidectomy. The persistence of this gland into adult life or its hypertrophy are not, however, constant accompaniments of hyperthyroidism. Lymphatic hyperplasia seems to have a similar inconstant though frequent relationship to the disease. Occasional changes have been reported in the hypophysis, parathyroid, and adrenals, but their involvement in hyperthyroidism is as problematical as that of the thymus. Almost every organ in the body may show some alteration as an accompaniment or result of hyperthyroid disease. There are sometimes punctate hemorrhages in the medulla and in the superior cervical ganglion of the sympathetic. In chronic or long-standing or in severe toxemic cases degenerative lesions in the cardiovascular system, liver, spleen, and kidneys are the rule.

Complications.—These have been referred to in the outline of the course of the disease. The most common in my experience have been the disorders which follow a rising or high blood pressure. Hypertrophy and dilatation of the heart or chronic nephritis are frequent in the chronic cases. A glycosuria or a psychosis are among the more dangerous of the complications. A colitis, with or without mucus, is sometimes very difficult to control. A susceptibility to infections, especially in the tonsils, is quite constant in hyperthyroidism. There is, also, considerable risk of intensification of the disturbance when operative interference must be undertaken upon other organs.

The Physiology of the Thyroid.—During recent years very few new facts have been added to the little which is known of the physiology of the thyroid. Its function is generally conceded to be confined to the production of its secretion. Several substances all containing iodine have been isolated from the gland, and all seem capable of producing some effect when administered to animals. But no single ingredient has been identified as the active principle of the secretion. In brief, there is no reasonable doubt that the biochemistry of the thyroid epithelium combines iodine with some organic material into a product which is a necessity in the biochemistry of growth and development in general, and of the genital organs in particular, especially those of the female; also, that the thyroid secretion is an important participant in the biochemistry underlying the activities of the central nervous system, the heart, liver, and probably the gastrointestinal tract and respiratory organs. There is every reason to believe that the thyroid product has some quantitative relationship to the activity of all these organs, and that the activity of the thyroid varies in amount according to the needs of any organ or group of organs. These needs must be expressed to the thyroid through the sympathetic or only demonstrable nerve supply of the gland, or through hormones circulating in the blood, or both.

As the most apparent action of the thyroid lies in its stimulation of metabolism, or in the increase of chemical processes which have the effect of increasing nutrition, it is possible for the present to classify the thyroid as an organ concerned chiefly in the production and expenditure of energy, or more briefly as an organ of nutrition. This designation serves at least as a partial answer to the queries presented by the therapeutic problems when the gland is diseased. It also helps to explain the adjective "nervous," which is constantly used to indicate some of the most striking characteristics of patients afflicted with thyroid abnormalities. As ordinarily

employed, "nervous" qualifies a personality or central nervous system which is more than usually sensitive to environment, and hence one which responds to all external and internal stimuli with more than the usual rapidity and thus requires the production and expenditure of more than the normal average amount of energy. If the thyroid, as seems true, can be classified with the organs of nutrition, it must be more or less constantly active to maintain a "nervous" person in health.

The association of iodine with the physiological activity manifested by the different substances which can be isolated from the gland is striking. The effects produced by the administration of any of these bodies seem roughly to vary in direct proportion to their iodine content. In conditions of hyperthyroidism, however, it is well known that the amount of iodine per gramme of gland substance is less than the normal amount, and the smaller this proportion the more severe as a general rule are the clinical symptoms. It has recently been demonstrated that electrical stimulation of the nerve supply of the gland produces a loss of iodine which increases with the duration and amount of the stimulation. In man, the only demonstrable nerve supply of the gland is a filament which arises from the superior cervical ganglion of the sympathetic, and follows approximately the course of the superior thyroid vessels and enters the gland near them. Sympathetic filaments also enter the gland in the walls of the arteries, and can be found around each alveolus.

Some of the more recent experiments are generally accepted as confirming the interdependence chiefly of the thyroid, pancreas, and adrenal-sympathetic or chromaffin system, and clinical observation for the most part has added to these the pituitary and thymus. The thyroid and the adrenals seem capable of mutual stimulation of activation, and both give evidence of some inhibition upon the pancreas. The pancreas in turn seems to inhibit the activity of the other two glands. The thymus also seems to present some inhibitory effect upon the chromaffin system. The frequent association of the pituitary, as in acromegaly, with goiter is apparent. The latest theory of disorders referable to these ductless glands revives in part the earlier conceptions of a primary neurosis of the sympathetic system, and includes the cranial and visceropelvic autonomic nerves. These constitute the visceral nervous system, and the parts arising from the medulla are the third, seventh, ninth, tenth and eleventh cranial nerves which are often involved in cases of thyroid disease. Von Graef's sign, or the retraction of the lids, manifested by inability of the upper to follow the lower lid in closing the eye; Stellwag's sign, or the "staring" eyes; and Moebius' sign, or inability to converge the axis of the eyes, and the contracted or dilated pupil, the lachrymation and the not infrequent ptosis are all referable to an increased or decreased "tonus" in the third nerve. Exophthalmos was once thought to be due to excitation of the superior cervical ganglion of the sympathetic, but the evidence at present seems in favor of its production by retroocular edema. The abundance of the oral secretions, sometimes amounting almost to salivation, is traceable to glandular activation through the seventh nerve. Dryness of the mouth and pharynx, which may cause an otherwise unexplainable cough, is sometimes present in hypothyroid conditions and may be due to a paresis of the glossopharyngeal. Some cases of hyperthyroidism show an increased tonus or activity in the tenth nerve, and others the opposite condition. The visceral nerves seem to convey opposing influences in different fibers, and practically all of the symptoms of functional thyroid disease can be traced to inhibition or excitation of the different organs by these impulses. If each of the ductless glands activates or inhibits some particular group of nerve fibers, at least a part of the relationship and interdependence of these organs becomes apparent.

Some recent experiments of Gudernatsch demonstrate most conclusively the interdependence of the thymus and thyroid, and the necessity of the thyroid in developmental processes. By feeding thyroid to tadpoles he has thus been able to change the creature almost immediately into the fully developed frog. But by withholding thyroid and feeding thymus the metamorphosis is entirely prevented. The thyroid must, therefore, be active during the metamorphosis of childhood into adolescence and maturity.

The Apparent Cause of Thyroid Abnormalities.—An abnormality of the thyroid means a simple hypertrophy of the gland, or the later solid or cystic degeneration which may take place or any condition of hypo- or hyperthyroidism. When these abnormalities advance from a less to a more severe stage, as described previously, there is always active functionation of one or more organs which are known to be in some degree dependent upon the thyroid. If there is more than the usual amount of activity in the nervous and vascular systems, or in the liver, or organs of the digestive or genital tracts any pre-existing thyroid abnormality is regularly intensified, and when these activities abate or cease there is regularly a corresponding relief of the thyroid symptoms. This means that conditions or circumstances which require active metabolism and a considerable production and expenditure of energy intensify all thyroid abnormalities. That they cause these abnormalities to begin in only a comparatively few individuals seems due to variations in the vital capacity of different thyroids, or to the variable amounts of energy which different individuals expend under corresponding conditions and circumstances. For the "nervous" person seems peculiarly subject to either the development of any thyroid abnormality or after its development, to its intensification. All thyroid abnormalities, as stated above, seem regularly to begin with simple hypertrophy, which is most reasonably interpreted as a multiplication of all the glandular elements to compensate for demands for a greater amount of thyroid secretion than the gland of natural size can supply. Activity in any organ is normally followed by a fatigue and, at least, partial cessation of function. In the case of the thyroid, the presumable compensatory hypertrophy which seems to be the first regular response to active functionation in the production and expenditure of energy, should be followed by fatigue and deficient functionation. This seems to be represented by the manifestations of hypothyroidism, or the second regular stage in thyroid disease. The other or later stages are apparently only evidence of a more intense degree of the same fatigue, although the reasons which cause one thyroid to undergo colloid or cystic or fibrous degeneration and another to undergo the changes and give rise to the symptoms of either myxedema or exophthalmic goiter, are entirely unknown. It seems possible, however, that the different directions in which thyroid abnormalities may advance are in some measure determined by the behavior of the fatigued thyroid epithelium in its attempt to metabolize iodine. In myxedema, the epithelium atrophies, and in hyperthyroid conditions it multiplies too rapidly and disintegrates, while the cystic goiters may involve a mechanical problem. Many of the latter forms of goiter evidently develop from more or less sudden hemorrhages into the substance of the gland. As clinically all types of hyperthyroidism are generally intensified by the administration of adrenalin or of the desiccated gland substance, and as the experimental evidence seems to link together the functions of the thyroid and adrenal glands, it is not impossible that the phenomena of hyperthyroidism involve some vicious circle in which the adrenals or cells of the chro-

maffin system participate and affect the biochemical activities of the thyroid epithelium.

If glandular fatigue is the ultimate or primary cause of all thyroid abnormalities, as seems probable, it then becomes possible to understand these disorders. When thyroid abnormalities appear in childhood their origin can be traced to the need of thyroid secretion to provide for rapid growth and development, especially if the brain is at the same time actively functionating. If one occur in a "shopgirl" or school teacher or trained nurse, it is presumably the result of excessive expenditure of energy by many organs, already taxed to their limit for maintaining the nutritional and metamorphic processes of young womanhood. Pregnancy, infectious diseases, traumatisms, and many other conditions or circumstances may thus originate or intensify thyroid disease. Endemic goiter need not be excepted, if only it can be regarded as beginning with a primary hypertrophy to compensate for excessive or unusual demands for thyroid secretion on the part of the liver or digestive tract or some other organ which must be active to dispose of the ingested bacterial or colloidal poison apparently proved to be its ultimate cause.

Treatment.—All the clinical data make it seem reasonable that hyperthyroidism is an expression of fatigue in a gland which is compelled by automatic stimuli to functionate beyond its natural capacity. Therefore, rest and protection of the organ chiefly at fault, is the most logical treatment. The kind and degree of quietude must vary with each individual, and the severity of the disease and a purely medical or conservative treatment will succeed in a considerable proportion of the cases in the early stages, and even in a small number of those which have advanced as far as the beginning of the fourth stage of exophthalmic goiter.

Of the medicaments which have been found more or less efficacious for thyroid disease, iodine is generally regarded as most important. But in the great majority of hyperthyroid conditions it must be used with caution if at all, because after an initial period of improvement, the gland generally becomes denser and larger, and this change is accompanied by a subjective sensation of constriction. Then, if the iodine is continued, the disturbance may be greatly and often dangerously intensified.

From what is known of the histology and comparative iodine content of the normal and hyperthyroid gland it seems possible that the epithelium is unable because of fatigue or other more complicated biochemical defect, to properly retain and metabolize iodine, and the access of iodine in excess to the gland occasions more work on the part of its secretory cells than they can perform. As a result, they break down and disintegrate into an imperfect colloid product which may be superabundant or of deficient quality or both.

The most valuable drugs are of the nerve sedative class, with the bromides and belladonna first in the list. Hydrobromide of quinine in five grain doses three or four times a day has a much greater reputation for amelioration of symptoms than it deserves. Digitalis or strophanthus may prove valuable in cases which do not show increased activity of the vagus by the pounding and manifestly increased vigor of the heart muscle. A heart which merely beats more rapidly than the normal without exaggeration of its contractions, may be steadied and slowed by digitalis and the patient ultimately much benefited. Organ feeding, in spite of our ignorance of its action, is certainly helpful if not curative in a small proportion of the cases, but seldom after the stage of hyperthyroidism has advanced into that of true exophthalmic goiter. It is suggestive of the possible variations in the nature or pathological physiology of the disease that the administration of thyroid by mouth has not infrequently proved helpful. That is the cause of the symptoms may not be due solely to an excess of the normal secretion, but to an excessive quantity of a product which has a defective quality, and that the quality may be improved by thyroid feeding with amelioration or cure of the disturbance is the legitimate inference to be drawn from many of the case reports. Thymus, pancreas, ovarian, pituitary, and adrenal administration may benefit this or that isolated subject, but no distinctive symptoms or indications can be given for the particular organ therapy which may prove best. The antithyroid serum for the treatment of hyperthyroidism has proved curative for about twenty per cent. of these cases, and of more or less help for some fifty per cent. additional. It is designed to inhibit the activity of the thyroid epithelium and to neutralize its product and is made by injecting sheep or rabbits with the combined nucleoproteins and globulins obtained from human thyroid glands. A full description of this product and its usage can be found in the *Annals of Surgery* for December, 1909. This serum, however, is curative for only a small proportion of all the cases of hyperthyroidism, and there is so much difficulty and expense in its preparation that it is impractical for general use. Treatment by the *x*-ray applied to the neck has many advocates, and a small proportion of cures are reported. In a considerably larger number some amelioration of the condition may be obtained.

But for all who do not recover, or at least show some signs of improvement after a few weeks or months of conservative and medical treatment, especially if they have passed beyond the stage of simple hyperthyroidism into that of exophthalmic goiter, some form of surgical interference is at present regarded as the most satisfactory. The ligation of one or more of the thyroid vessels, or the excision of one-half or more of the gland yields about fifty per cent. of cures, and at least some twenty-five per cent. in addition of improvements with a mortality in experienced hands of between one and ten per cent. The treatment by partial thyroidectomy will be discussed first. The ultimate mortality in medically treated or unrecognized cases from hyperthyroidism and its complications is variously estimated as between five and ten per cent., or a much higher figure than is ordinarily recognized, and it often means years of helpless invalidism or suffering. The worst that can be said against the radical operation by removal of part of the gland is the considerable number of cases which it fails to cure, or which subsequently relapse. In addition, there are a few which are made worse by hemithyroidectomy. On the other hand, there is no doubt that at least half, and probably more, are quickly and permanently relieved. Some of those who are not cured or who relapse after partial thyroidectomy can be benefited by subsequent removal of more of the gland. As yet, it seems impossible to accurately select the cases which are best suited for this form of treatment, but a few general rules of a negative nature can be formulated, which have been learned from an observation of many poor or bad postoperative results. Partial thyroidectomy is to be avoided as extremely dangerous in all cases which in spite of the best medical care and of rest show a noticeable intensification of the symptoms of hyperthyroidism. The appearance or even the suggestion of a psychosis greatly increases the operative risk. Because of relapses and of failures to cure, partial thyroidectomy is to be avoided in patients who have not completed or have recently completed their maximum of growth and development; it is to be avoided in symmetrically enlarged glands as these seem peculiarly prone to relapse even after considerable periods; it is to be avoided also in patients who generally show marked symptoms but have only small goiters which means a gland not more than double the normal size; and in subjects of the very "nervous" type whose mentality is really that of a psychosis. Patients with marked exophthalmos bear any operation badly, and can seldom be more than moderately improved.

In doubtful cases some idea of the patient's ability to withstand the radical operation can be obtained with reasonable safety by the preliminary ligation under local anesthesia of one, generally the superior, group of vessels. If this is borne easily and without any severe reaction, the removal of half the gland can be undertaken a week or two later with some security. if not, the ligation of other vessels is the only resource, but should not be attempted before the organism is again in stable equilibrium, as a fatality is not uncommon even from this slight interference.

The condition, or what is here assumed to be the stage, of hyperthyroidism represented by exophthalmic goiter is seldom perfectly cured by any method of treatment, and in an attempt to improve upon these results I have practised under local anesthesia in two stages the ligation, and generally the division of all four of the chief thyroid vessels in a considerable proportion of these cases, and there has occurred no resultant myxedema or other disastrous result. This operation cuts off the chief part of both the vascular and nerve supply of the gland, and is designed to enforce rest upon a presumably fatigued organ which shoulp be preserved and not sacrificed.

The superior vessels are reached by the usual transverse incision, and the tips of the lobes are generally to be included in the ligature and excised to ensure the division of the arteries. The lower arteries are to be reached through a vertical incision over the lower end of the posterior border of the sternomastoid. This approach exposes and passes in front of the phrenic nerve on the scalenus anticus. The inferior thyroid can then be felt and reached behind the internal jugular and common carotid.

The improvement after quadruple ligation of the thyroid blood supply, which must include the lower nerve supply and generally all or most of the upper, is not as rapid as after partial thyroidectomy, but the operation seems to be more certain in its results and less dangerous to life, and the patient has less subsequent risk of relapse even under the conditions and circumstances which seem to produce thyroid abnormalities. In the case of partial thyroidectomy these must be removed and for at least one year or relapse is very probable. After quadruple ligation, however, hygienic measures are desirable, but their perfect observance is not essential for a cure. In several of my earlier cases the improvement became stationary, apparently because of the continuation of the unfavorable environment and exploration revealed a reformation of one or more arteries at the upper poles of the thyroid apparently from small collateral branches not secured at the primary operation. It is technically difficult to be sure of securing all the twigs given off from the superior thyroid, especially in a nervous subject under local anesthesia. General anesthesia seems to add materially to the risks, and is to be avoided according to the experiences of most operators. Hence, if any evidence of delay in recovery or relapse appear there should be no hesitation in advising secondary operation to reobliterate the probably new circulation at the upper poles of the gland. Resection of the tips of the lobes seems to be better than simple division of the upper vessels. In judging of the results, the general condition is of more importance than separate symptoms.

Only one or two arteries should be tied at a sitting, and the operation should not be continued long enough to cause more than moderate fatigue.

To *recapitulate*, briefly, the indications for and the forms of treatment: Rest and good hygiene are essential for the cure of any thyroid disease; the antithyroid serum is the most efficacious of all conservative methods for many cases in the early stages of hyperthyroidism and for some of these in the exophthalmic group. In dosages of ½ to 1 c.c. it is harmless, but if its exhibition intensifies the symptoms it should be discontinued. When conservative methods fail after a month's trial, the ligation of one or more thyroid vessels should be practised, or the excision of half the gland. Local anesthesia is preferable to general narcosis. Ligation of one or more of the chief thyroid vessels will cure a considerable proportion of all types of hyperthyroidism. It is safer, but much slower in its effects than hemithyroidectomy. For exophthalmic goiter, ligation of all four thyroid vessels seems to offer better hopes of cure than the more radical operation. Hemithyroidectomy seems indicated especially in the third or hyperthyroid stage of the disease rather than in the fourth or that of exophthalmic goiter, and in patients over twenty-five years of age who possess asymmetrical goiters of considerable and not small size.

About twenty-five per cent. of all cases of hyperthyroidism are only improved by the hemithyroidectomy some ten per cent. are not benefited at all or made worse, and the general operative mortality is at least five per cent.

Surgery at the best is but a rough approach to the means which a better knowledge of physiology and of organ therapy should provide for the relief of these patients. JOHN ROGERS.

Gold.—See *Aurum*.

Gold Equivalent.—Certain hydrophile colloids which are not readily precipitated by electrolytes have the power of protecting suspension colloids against the precipitating action of electrolytes. The figure in milligrams of colloid that is just insufficient to protect 10 c.c. of gold solution (0.0053–0.0058 per cent.) against the action of 1 c.c. of ten-per-cent. sodium chloride is called the gold equivalent for the respective colloid. Gelatin offers the best protection, then comes isinglass, casein, ovalbumin, gum arabic, Irish moss, dextrin, starch. F. P. U.

Goldthread.—See *Coptis*.

Goll, Friedrich.—Born March 1, 1829, in Zofingen, Switzerland, and studied in Zurich under Ludwig, in Würzburg under Virchow and Köllicker, and in Paris under Claude Bernard. He obtained his medical degree in 1853. He turned his attention first to pharmacology, and also had quite an extensive genito-urinary practice, but soon became specially interested in neurology, especially in the anatomy of the central nervous system. He was made a member of the medical faculty of the University of Zurich in 1885. He died November 12, 1903, after a long illness.

Goll described the fasciculus gracilis of the spinal cord (usually called Goll's column), the collection of ganglion cells at the proximal extremity of this column in the region of the clava (Goll's nucleus), and fibers running from this nucleus to the vermis (Goll's fibers). Among his anatomical writings were: "Die Vertheilung der Blutgefässe auf die Rückenmarksschnitte," 1864; "Ueber die feinere Anatomie des Rückenmarks," Zurich, 1868. T. L. S.

Gonococcus Infection, General.—It is now generally recognized that the gonoccocus may enter the circulation from any local lesion and cause either a gonococcal septicemia or a localized metastatic process in the most varied regions of the body. How often this occurs cannot be ascertained from the literature. Increasing stress is laid upon the possibility of such an occurrence in the text-books, but abundant statistics are lacking. It is only in the teaching hospital or laboratory that the great majority of metastatic gonococcal lesions can be definitely demonstrated; in the ordinary practical treatment of this affection such metastases of the etiologic agent are usually not suspected and, with the exception of the joint complications, are rarely recognized. Nevertheless, it is surprising when any relatively small group of ordinary

gonorrheal cases are carefully studied over a period of time from a laboratory standpoint to find so many cases showing evidences of a general involvement (fever) or more or less severe localized metastatic involvements. It is highly important that gonorrhea should be studied clinically more often from a standpoint of a general infectious disease than as a purely local affection. When this is done it is very probable that the clinical importance of generalized or metastatic gonococcal infection will be still more fully appreciated than at the present time. Yet the practitioner of to-day has a far different attitude toward the importance of gonorrhea of the genital tract than that held by his predecessors a generation ago; and because of the possibilities now known to attend upon such an infection he has come to look upon the gonococcus as an etiologic agent of the first rank.

The general or localized metastatic infections produced by the gonococcus offer problems of etiology and pathogenesis similar to those caused by the streptococcus and staphylococcus. Why the gonococcus should gain entrance to the blood and grow there in certain cases with the production of serious results, while in many other cases no evidences of such a successful entrance can be discovered can at present only be discussed from the general standpoints of individual differences in susceptibility or resistance and differences in strains of the organism. That a great variation exists in the biological characteristics of the gonocoeci obtained from different sources has been shown by the work of a number of investigators. It is also certain that the action of the blood serum of different individuals upon the infecting gonococcus differs greatly. From pathologic studies of the local lesion in the male urethra it seems very likely that even in the mildest forms of acute gonorrheal urethritis some gonococci may enter the blood-stream. Probably in fifty per cent. of mild cases these organisms entering the circulation are killed at once without causing any injury; in other cases the virulence of the infecting strain or the lowered resistance of the infected individual enables the gonococcus to grow in the blood or to set up metastatic processes. Various writers state that a general infection takes place only when the posterior urethra is involved; but sufficient evidence has accumulated to show that any localization of the gonococcus (anterior urethra, bladder, prostate, oviduct, conjunctiva, etc.), may be the source from which a general infection or a metastasis may take place. Wertheim was the first to show the entrance of gonococci into the small veins of the bladder; but the organism has since been repeatedly cultivated from the circulating blood.

General Gonococcal Infection.—*Gonococcus Septicemia.* The occurrence of a gonococcus septicemia has been reported with increasing frequency in recent years. The condition may follow a mild or severe acute gonorrhea, or be secondary to some metastatic localization, such as epididymitis, orchitis, vesiculitis, prostatitis, bubo, peritonitis, subcutaneous abscess, pleurisy, pneumonia, iritis, conjunctivitis, pyelitis, arthritis, etc. Endocarditis may or may not be associated with the septicemia. In twenty-nine cases collected by Cole it was present in only eleven cases. In the cases without endocarditis the symptoms resemble very closely those of typhoid fever, and the great majority of cases of gonococcal septicemia are probably treated as for that disease. There is a continuous fever, usually showing marked daily remissions, with headache, general malaise, enlarged spleen, and a general picture closely resembling that of typhoid fever. In very mild cases the symptoms are those of a mild septicemia, or may even be mistaken for those of incipient tuberculosis. In the cases associated with endocarditis the clinical picture is that of a mild or a more malignant type of endocarditis. In the latter case there are high fever, chills, sweating, mild jaundice, petechial hemorrhages, and symptoms of infarction.

Some writers on puerperal fever are inclined to look upon the gonococcus as an important etiologic factor in the production of this condition, even to the extent of causing twenty-five to thirty per cent. of all cases of puerperal fever. Such an opinion is undoubtedly based upon the frequency of coincidence of the two conditions, not upon any actual demonstration of a gonococcal etiology of the fever. In Cole's twenty-nine cases of gonococcal septicemia only two were instances of the puerperal septicemia.

The diagnosis of gonococcal septicemia rests upon the demonstration of gonococci in the circulating blood. The specific reactions may also be made, but these have not yet been sufficiently tried out clinically for us to estimate correctly their diagnostic value. Cole's method for the cultivation of the gonococcus from the circulating blood is as follows: 10 c. c. of blood should be taken, under proper precautions, from one of the larger veins, by means of sterile syringe. The blood is added to melted agar in the proportion of 1 to 2 to 3, the mixture is then poured into Petri dishes and allowed to set. The melted agar must not be heated above 40° C., as the gonococcus is easily killed at this temperature. After twenty-four to forty-eight hours at body temperature the small colonies of gonococci can be easily recognized if the organism is present.

The blood should be cultivated in all cases of typhoid-like fevers occurring in association with active gonorrhea, either acute or chronic, or in the case of infections supposedly cured. Investigation as to the possibility of such an infection should always be made, particularly in the case of young men who develop atypical typhoidal conditions without a positive Widal reaction. In cases of this kind the specific tests for gonococcus infection should also be employed if the history of the gonorrheal infection is not a recent one.

Gonococcus Pyemia.—Some cases of generalized gonococcus infections present the general picture of a pyemia, being characterized by the occurrence of metastatic abscesses in association with the septicemia. Such abscesses may be found in the skin and various internal organs such as the lungs, parotid gland, prostate, seminal vesicles, lymph nodes, etc. Complete pathological studies of such gonococcus pyemias have not yet appeared in the literature, and our knowledge concerning these amounts to but little more than the fact of their occurrence.

Treatment.—The treatment of gonoccocus septicemia and pyemia is the same as for all other forms of these conditions. Gonococcus pyemia becomes a surgical condition whenever the abscesses can be operated upon and drained. The specific treatment by antigonococcus serum or vaccines may be tried in the milder or more chronic cases. Vaccine treatment may cause an increase in the local lesion, with the result that an organ like the prostate may be completely destroyed by such an acute exacerbation of the suppurative process.

The prognosis in gonococcus septicemia and pyemia is probably, on the whole, favorable as far as life is concerned. It is obvious that only the severe forms will be observed and recognized; while it is impossible to state how many cases of mild grades escape recognition. Even in the case of the severe forms that have been recognized during life the prognosis seems relatively more favorable than in streptococcus septicemia. Of the twenty-nine cases collected by Cole sixteen recovered. It is probable that the cases with endocardial lesions are more unfavorable.

Gonococcus Toxemia.—Our knowledge of the toxin of the gonococcus has not been materially advanced since the studies of de Christmas, Wassermann, and

others. The exact nature of this toxin is still unsettled, although it is regarded by many writers as an endotoxin. Injections of killed cultures of gonococci cause fever, headache, pains in the bones and joints, nausea and vomiting. Marked symptoms of a general intoxication are sometimes seen in cases of gonorrheal prostatitis, vesiculitis and salpingitis. Slight fever, ringing in the ears, dizziness, pain in the bones and joints, neuralgia, neuritis, sciatica, myelitis, mental depression, neurasthenia, hysteria, and other psychical conditions are sometimes promptly relieved by control of the local process by operation, "milking" the prostate and seminal vesicles, or by removal of a pus tube. Parenchymatous nephritis and amyloid disease may develop in association with chronic gonococcal infections, as in cases seen by the writer. To what extent these varied symptoms are due to the action of an endotoxin or to a toxin produced by the metabolism of the gonococcus, or to poisons arising secondarily to the gonococcus process cannot at the present time be determined. The view formerly held that the majority of these conditions are reflex in origin has at the present time yielded somewhat in favor of the view that they may be due to toxins.

Metastatic Gonococcus Lesions.—*Arthritis.*—Of the metastatic lesions of gonorrhea the most frequently recognized one is gonorrheal arthritis. Its frequency is estimated at two to fifteen per cent. of all cases of gonorrhea, but is probably higher than this, inasmuch as many cases are mild or develop after the urethritis has become past history so that the relationship to the infection is lost sight of. By many writers gonorrheal arthritis is regarded as the most common form of joint trouble; sixty to eighty per cent. of all cases of lameness of the knee in young and middle-aged men are said to be due to this infection. It is more frequent in men than in women; and may occur at any age. In infants it may be secondary to ophthalmia neonatorum or to gonoccocal vaginitis. It may follow any localization of the gonococcus, an acute mild urethritis as well as the severe and chronic infections. In women it not infrequently develops during the puerperium.

The frequency with which arthritis develops in gonorrhea must be taken as evidence of the frequency of entrance of the gonococci into the circulating blood. The writer is very strongly of the opinion that gonococci enter the blood stream in every case of gonorrheal urethritis, no matter how mild this condition may be. The resulting damage depends upon the two factors mentioned above, the virulence of the infecting strain and the bactericidal action of the blood. Should the gonococci entering the blood survive, the third factor of the *locus minoris resistentiæ* must then be considered also. The predilection of the gonococcus for the joints may possibly be explained on the ground of the frequency of injury of these joints, both from trauma and infection with other organisms. The view that the toxin of the gonococcus is primarily responsible for the joint involvement is not tenable. Bacteriologic examination of the fluid obtainable from the joints in the early stages will usually show the presence of gonococci; in later stages the fluid is either sterile or contains staphylococcus forms. In a certain proportion of cases cultures of the blood taken early will show the presence of gonococci in the circulation. Gonococcal arthritis is, therefore, probably always due to the presence of the gonococcus, and is the result of a hematogenous metastasis.

Pathology.—Gonorrheal arthritis may present a pathological picture varying from a simple serous, serofibrinous, or purulent arthritis to a phlegmonous peri- or para-articular inflammation. No sharp line can be drawn between these forms, although some writers (König) regard the classification of these different forms as important. The mild cases are usually serous and present a simple hydrops of the joint; the moderately severe ones show a seropurulent or a serofibrinous inflammation. The synovial membrane is swollen and injected, and there is edema and leukocyte infiltration of the periarticular tissues. In the acute stages no changes are found in the bones or cartilages. The severe cases present an empyema of the joint, and the cartilages and bones show more or less erosion. Later stages show more or less pericapsular thickening, and occasionally formation of osteophytes and bony ankylosis. As the case becomes chronic with marked limitation of movement the bones show atrophy and osteoporosis. All of these changes may be seen by means of the *x*-ray; but the *x*-ray examination reveals nothing that can be said to be specific of gonorrheal arthritis, in spite of assertions to the contrary.

Symptoms.—The very mild cases show only tenderness or pain in the joint, general malaise and little fever. Such cases may run a very short course. The more severe cases have red, hot, swollen and very painful joints, with distinct fever, chills, sweating, general malaise, the general picture being that of acute rheumatic fever. The onset is usually very acute, although prodromal symptoms of general malaise may occur. Exposure to cold and wet, fatigue and trauma may precede the onset. The majority of the cases show a polyarthritis at first, although in the later stages the involvement is more often monoarticular. The smaller joints may be primarily involved, the larger joints later, although the latter may be involved from the beginning. The involvement of the small joints is usually transitory. In a general way the involvement of the joints corresponds to that seen in acute rheumatic fever, except that the temporomaxillary joint is frequently affected in gonorrheal arthritis, while extremely rarely involved in acute rheumatism. The tenderness and pain are increased by movements of the joints and by stretching of the capsule when the effusion is large. The fluid obtained by aspiration of the affected joint may be serous, seropurulent, serofibrinous or purulent; it may be clear, turbid, greenish, or brownish in color.

Gonococcus arthritis must be differentiated from acute rheumatic fever, pneumococcus arthritis, septic arthritis, gout and tuberculosis. The differential diagnosis is not always easy. The involvement of the temporomaxillary joint, the persistence of the affection in one joint with abundant effusion, the history of urethritis, and the demonstration of gonococci in the fluid from the joint are the main diagnostic points to be considered.

The treatment consists in measures directed against the primary gonococcus focus in the urethra, prostate, seminal vesicles, or wherever it may be located. A polyvalent immune serum should be tried in the acute cases; while gonococcus vaccines should be tried in the chronic ones. Bier's passive hyperemia aspiration and surgical measures to prevent erosion of the cartilages and ankylosis should be adopted.

Arthritis deformans, spondylitis deformans, painful heel (*talalgia*), *periosteitis, osteitis, osteomyelitis, chondritis, perichondritis,* and *tenosynovitis* have all been shown in certain cases to be due to metastatic localizations of the gonococcus. In individual instances of these affections gonococci have been demonstrated as positive causal factors; but our knowledge of their pathology is still very limited.

Gonococcus Endocarditis.—Next to gonococcus arthritis the localization of gonococci upon the cardiac valves is probably the most important metastatic affection caused by this organism. The first case in which the gonococci were positively demonstrated in the smears from the cardiac vegetations and from the circulating blood is that reported by Thayer and Blumer in 1895, although Ricord as early as 1847 had called attention to the association of endocarditis with gonorrhea and gonorrheal arthritis. The cases have been reported with increasing frequency in

recent years. Young men form the greater part of the material, although the condition has been seen in children and in old people. As in the case of the arthritis the endocardial involvement may take place in acute and mild cases of urethritis, as well as in the more severe and chronic forms. Metastasis to the heart valves may occur from any localization of the gonococcus.

In gonococcal endocarditis there is a more especial tendency to involvement of the right side of the heart than there is in other forms of endocarditis, although the aortic valves show the greatest frequency of involvement. The valvular lesions may present the appearances of a simple, verrucose, or ulcerative endocarditis. There is an especial tendency to the formation of large polypoid thrombi upon the affected valve. In two cases seen by the writer these polypi had a peculiar greenish color. Embolic infarction was not present, although occurring in other reported cases. Death resulted from acute dilatation of the left ventricle, following obstruction at the aortic orifice. Gonococci may be found in the circulating blood in association with a simple endocarditis, or smears from the thrombus may show cells filled with gonococci.

The symptoms of gonococcus endocarditis are the same as of a simple or a malignant endocarditis due to other pyogenic cocci. There is an intermittent or remittent fever, chills, sweating, marked prostration, petechial hemorrhages and progressive anemia. The cases may vary in severity from the mildest to the most severe. Arthritis may or may not be associated with the condition. There is usually a moderate leukocytosis. Embolic infarction, acute nephritis, pneumonia, pericarditis, pleuritis, and peritonitis may complicate the condition. *Gonococcoccal myocarditis* and *pericarditis* have been reported. Gonococci have also been demonstrated in smears from necrotic areas and suppurative foci in the heart muscle.

The diagnosis during life depends upon the association of an endocarditis with gonococcus lesions elsewhere in the body, and upon the demonstration of the organism in the circulating blood. All cases of gonorrheal urethritis having fever should receive a careful examination of the heart; it is wisest to regard these cases as suspicious and advise perfect rest. Cases of recovery from gonococcal endocarditis have been reported, and it is very probable that many are of a mild character. The treatment is the same as that for other forms of endocarditis.

Vascular Lesions.—Arteritis and phlebitis of the pelvic blood-vessels are very common in association with gonorrheal infections. Thrombophlebitis of the prostatic plexus is apparently a very frequent complication of gonorrhea, and gives rise to phleboliths in these vessels that are sometimes the cause of misinterpretations of *x*-ray plates as ureteral calculi. Phlebitis of the larger veins of the leg, particularly the internal saphenous, is associated frequently enough with gonorrheal urethritis and arthritis to make it very probable that the gonococcus is the direct etiologic agent, although the organisms have not yet been positively demonstrated in the vessel walls.

Pneumonia.—Gonococcal pneumonia has been reported by a number of observers; but the rôle played by the gonococcus in the pneumonias occurring as a complication of gonorrhea cannot be said to be definitely settled. The same thing is true of the cases of *pleuritis* thought to be gonococcal in origin. There is great need for more careful bacteriological studies of these complications of gonorrhea in order to settle definitely the etiological rôle of the gonococcus.

Nervous System.—Complications on the part of the nervous system occur frequently enough in association with gonorrheal urethritis to make it very probable that the association is not purely one of coincidence. Either the gonococcus or its toxin must be primarily responsible for certain nervous lesions, or gonorrheal infections must predispose to their development. The most important of the nervous conditions associated with gonorrhea are meningomyelitis, meningitis, myelitis, neuritis, sciatica, neuralgias, and various psychical disturbances. The gonococcus is reported as having been demonstrated in meningitis. The spinal cord lesions are interpreted by some writers as reflex in origin, by others as an ascending neuritis, or as due to the direct action of the gonococcus or its toxins. Sciatica is especially common in women who have acute urethritis. Neuritis in the nerves adjacent to an infected joint is relatively common.

The *psychical* disturbances attending chronic gonorrheal infections are sometimes of the greatest clinical importance. They vary from a slight feeling of depression, "blues," to marked melancholia, neurasthenia, hysteria, psychoneuroses, or insanity. They are not infrequent complications of gonorrheal prostatitis, vesiculitis, epididymitis, arthritis and salpingitis. By many clinicians they have been regarded as purely reflex or secondary in origin, while others regard them as toxic. In general it may be said that no characteristic clinical or pathologic picture is presented by these nervous complications.

Kidney.—Parenchymatous nephritis may exist as a complication of chronic gonorrheal salpingitis. Amyloid kidney has been seen by the writer as a complication of the same gonococcus localization. Abscesses of the kidney containing gonococci in pure culture have also been observed.

Eye.—Metastatic conjunctivitis, iritis, keratitis, retinitis, neuroretinitis, cyclitis, iridocyclitis, iridochoroiditis, tenonitis, optic neuritis, dacryoadenitis, and ocular myositis have been reported as occurring in gonorrhea, but the exact etiologic relationship of the gonococcus to these processes is not yet fully demonstrated.

Skin Lesions.—Much interest attaches to the skin eruptions sometimes seen in association with gonorrhea. They may appear as a simple erythema, erythema nodosum, urticaria, hemorrhagic eruption, bullæ, etc. Here again the etiologic relationship is not clear. A peculiar and apparently specific skin lesion associated with gonorrhea is the so-called gonorrheal keratosis of the soles and palms. It is usually associated with arthritis, and disappears when the joint condition is healed. Of the exact pathologic nature of this complication and its relationship to the gonococcus we have no definite information. By some writers it is regarded as a trophoneurosis. Metastatic abscesses containing gonococci have been observed in the skin and subcutaneous tissues in cases of gonococcal pyemia.

Muscles.—The muscles in the neighborhood of an infected joint show atrophy and a more or less extensive inflammatory process. Metastatic abscesses in the muscles are of rare occurrence in gonococcus pyemia.

Lymph Nodes.—Metastatic abscesses containing gonococci have been reported as occurring in lymph nodes.

Specific Reactions for Gonococci.—The presence of specific antibodies in the blood of individuals infected with the gonococcus has been made the basis of various attempts to obtain a specific diagnostic method that could be used clinically with greater ease and certainty than the cultivation of the organism. Much experimental work has been done in this direction during the last decade; but it yet remains to be seen whether there has been obtained any better diagnostic procedure than the cultivation of the gonococcus from the lesion. The various methods concerned with the demonstration of the specific antibodies (opsonin, agglutinin, bacteriolysin) in the

blood have been generally regarded as possessing little or no diagnostic value. Somewhat more importance is attached to the methods of Cole and Meakins, Schwartz and O'Neill (*Amer. Journal of the Med. Sciences*, 1911, 1912) in which fixation of the complement is made use of in determining the presence of the antibodies. Through the employment of a polyvalent antigen a positive reaction can be obtained in a certain number of cases of gonococcus infection four or five weeks after the beginning of the process. A negative reaction cannot be regarded as positive evidence that a gonococcus infection is not present. While this reaction may possess some value in chronic cases, its range of application is limited and the method too uncertain to make it of great clinical service.

More attention has recently been given to the methods in which a reaction in the living body is obtained by the injection of killed cultures of gonococci or by the application of a glycerin extract of gonococci, "gonococcin," to a slight abrasion of the skin. The work of Irons along this line has been especially regarded as offering diagnostic methods of distinct advantage because of the ease of procedure. The injection of a killed culture of five hundred million of gonococci produces in individuals having a gonococcus infection a general exacerbation of the symptoms (urethritis, arthritis, etc.), with fever, headache, nausea, and vomiting. Normal individuals should show no reaction to a dose of this size. At the seat of the injection in the normal individual there should be no reaction, but in the infected individual there are often local tenderness, redness, and swelling. When a drop of the glycerin extract of gonococci ("gonococcin") is applied to the broken skin after the manner of the von Pirquet test there should occur after some hours in the patient who has a gonococcus infection a papule surrounded by a zone of hyperemia, while in the non-infected individual there should be little or no reaction.

These methods are all still in the experimental stage, and it is too early to speak positively concerning their value. As matters stand now the cultivation of the gonococcus from the blood, or its demonstration in the lesion is still the most conclusive diagnostic method; but this method has also serious limitations. The attempted demonstration of the gonococcus in smears and in sections is also of little value in the recognition of chronic cases, particularly those of the "carrier" type. The tendency of the gonococcus to assume involution forms indistinguishable from staphylococcus, and the relationship of these staphylococcus forms to the pathological conditions offer problems still unsettled. When positive results are obtained by any one of the methods given above it may be accepted as a positive evidence that a gonococcus infection is present; but negative results have even less value than negative Wassermann reactions in the diagnosis of syphilis.

Specific Treatment.—Specific treatment of general infections and metastatic lesions of gonorrhea is being given much attention at the present time, but clinical reports are very conflicting. Specific antisera from immunized animals have been tried without much success. The treatment by vaccines has given more promising results in the case of chronic affections; autogenous or polyvalent vaccines should be used. Beyond this general statement such treatment must be regarded as experimental in any given case; dosage and time intervals must be individually determined. The majority of clinicians now agree that the determination of the opsonic index is of no value in the control of the treatment.

Aldred Scott Warthin.

Gonorrhea.—Gonorrhea is a common disease usually contracted during sexual intercourse, which attacks the mucous surface of the genitourinary tract and the connecting glands. It is caused by the gonococcus, an intracellular diplococcus. Since the identification of the gonococcus, it has gradually assumed greater and greater importance, especially as regards the serious character of gonorrhea when spread to the pelvic organs in both men and women. Gonorrheal eye infections also cause a large percentage of blindness in adults as well as infants. Serious and disabling joint affections are not infrequently caused by the gonococcus. General systemic infections with this organism are occasionally observed.

The Gonococcus.—This organism is a diplococcus about one micron long, and three-fourths of a micron broad. It does not stain by Gram's method, nor can it be cultivated on nutrient agar at ordinary room temperature as can the *Micrococcus catarrhalis*, which is the organism most likely to be mistaken for the gonococcus. The gonococcus will take any of the basic aniline dyes. For ordinary work a two per cent. aqueous solution of methylene blue affords a satisfactory stain. The meatus is washed and the specimen is taken from just within the urethra with a platinum loop. This should be spread in a thin layer on a slide and fixed by passing a few times through a flame. It is then stained and observed with the oil immersion lens. If doubt exists, and an absolute diagnosis is necessary, cultures should be made by an expert bacteriologist, along with control cultures of a positive gonococcus.

Etiology.—The gonococcus is always the cause of gonorrhea, but the likelihood of infection is increased by contributing factors, such as prolonged or excessive sexual intercourse, failure to cleanse thoroughly after the completion of the act, a long foreskin which retains the infected secretion in contact with the meatus, alcoholism, and finally an apparent lack of tissue resistance, as some patients are apparently more susceptible than others. Urethritis may be caused by other organisms than the gonococcus as well as by toxic, chemical, and traumatic agencies.

Pathology.—The organisms are usually implanted on or just within the meatus, and there proliferate, spread, and penetrate. As they develop the leucocytes and serum escape, producing the discharge. The organisms gradually extend throughout the urethra and its adnexa causing abscesses, inflammation of the lymphatic glands of the groin, epididymitis, and perhaps finally arthritis, endocarditis, and peritonitis. In women the urethra, vulva, vagina, cervix, endometrium, Bartholin's glands, Skene's glands, the Fallopian tubes, and ovaries may be involved. In babies the infection is usually limited to vulvovaginitis and urethritis.

Symptoms.—*Acute Gonorrhea.*—After an incubation period from three to six days, the manifestations of the disease begin as a slight itching and burning sensation about the meatus on urination; soon a mucous or mucopurulent discharge is seen. The inflammation and discharge increase and the pain and burning become more severe. The urine shows much pus and many shreds in the first glass, and later all glasses may be cloudy. Involvement of the prostate and seminal vesicles is attended with strangury and symptoms of cystitis. Among other symptoms and complications are chordee, folliculitis, balanitis, lymphangitis, inguinal adenitis, epididymitis, rheumatism, etc.

The symptoms of *chronic gonorrhea* are discharge, recurrent or persistent, pus and shreds in the urine, and various urinary or genital disturbances depending upon the involvement of the different organs.

Diagnosis.—The diagnosis of anterior urethritis is readily made from the history and a microscopic examination of the secretion. It is of much importance to determine whether or not the infection is limited to

the anterior urethra or whether it has spread more deeply and to the glands. During the first week the infection is limited, as a rule, to the anterior urethra. This may be determined by gently irrigating the anterior urethra with a physiological salt solution, and then allowing the patient to urinate. If the inflammation has extended beyond the "shut off" muscle the urine will show pus after the anterior irrigation. Gonococci do not remain limited to the anterior urethra for a very long time—probably not longer than a week in the majority of patients. The manifestations of acute deep urethritis need not necessarily follow infection of this part of the urethra, subacute and chronic infections of the deep urethra and prostate may exist without any symptoms to suggest their involvement. Therefore, the diagnosis must be made by an examination and not by the history and symptoms. We should always suspect deep-seated or pocketed infections in the patients who do not readily respond to the ordinary treatment.

Prognosis.—Generally speaking the outlook may be considered good, as the great majority of patients who receive suitable treatment make satisfactory and complete recoveries. Chronic prostatitis, seminal vesiculitis, and infection of urethral follicles may require very tedious and prolonged treatment. This is especially true of vesiculitis. The modern treatment of gonorrhea is rarely followed by urethral stricture.

Abortive Treatment of Acute Gonorrhea.—When patients with gonorrhea are seen the first or second day after the discharge appears, provided the incubation period has not been unduly prolonged, and provided intercourse has not been indulged in during this time, and provided further that no treatment has been used to spread deeply the infection, a considerable percentage can be cured within five days by retaining an argyrol solution in the anterior urethra for six hours daily. Patients may be trained to come promptly after the appearance of the discharge without any meddlesome interference for a microscopic diagnosis. After being cured by this method once, there is little difficulty in having them come early, even though it envolves considerable expense and a long railway trip. No matter what the organisms may be, if they have not extended more deeply than the part subjected to the argyrol, success is sure to be obtained; if they are deeper than the mucosa receiving the medication, then failure is sure to result.

Technique of Sealing the Argyrol in the Urethra.—Those who wish to employ this treatment should practise upon patients with chronic infections until they have acquired the slight knack which is necessary. It does the patient no harm, and does the surgeon much good, as he may be able then properly to seal the solution in the urethra at a critical moment when dealing with a beginning acute condition which can be quickly cured.

After the microscopic examination proves the diagnosis, the patient empties his bladder and reclines upon an operating table. The penis is well cleansed and dried; a towel is placed around it and twenty-five to thirty minims of a five per cent. solution of argyrol, freshly prepared, are injected into the urethra with a small blunt-pointed urethral syringe.

The index finger and the thumb of the left hand compress the anterior portion of the urethra, so as to prevent the solution from escaping. The meatus is dried thoroughly, and its edges coapted and pressed together. A bit of cotton is placed upon the glans penis—*not over the meatus*—and held in this position while collodion is applied with a camel's-hair brush. The collodion is applied several times until the meatus and one-fourth of an inch around it is well covered; it is also applied on the cotton so as to furnish a tag by which it can be removed. It requires from three to four minutes for the average collodion to dry, and it should not be released until it is thoroughly dried. The cotton is now trimmed away so as to leave only a small tag. The patient goes about his usual duties, and avoids urinating as long as possible. He should retain the argyrol from four to eight hours daily for five days. The solution of argyrol should be prepared freshly every few days, as stale solutions are less potent, and more irritating. In order to flush the urethra freely, the patient is advised to drink about a half gallon of water after the sealing is removed. When apparently cured the patient may be allowed to drink several bottles of beer. If the cure is complete no harm is done. If infection still exists the quicker it is known the better, as further treatment can be instituted more promptly.

After the fifth day, or earlier, if the progress does not seem satisfactory, the routine treatment with irrigations and urethral injections should be instituted.

Routine Treatment.—If the patient is seen too late to use the sealing-in treatment, or if this treatment fails, the patient should be given an irrigation of the urethra and the bladder once or twice daily with a Valentine irrigator. The best solution is potassium permanganate 1 to 7,000 or 1 to 8,000 in a hot physiological salt solution. The patient will make more rapid progress when mild solutions are employed than when they are sufficiently strong to cause a burning sensation in the urethra after the treatment. We do not even resort to stronger solutions later, as we find that better results follow the weaker solutions. While giving the irrigations the patient stands and holds a basin in which to catch the solution, the penis is thoroughly cleansed and the bladder partly or completely emptied. The anterior urethra is first irrigated, using about one pint of the solution. The retort is then raised to about three feet above the penis and the blunt urethral nozzle is pressed more closely against the meatus and the patient is instructed to make an effort as if trying to urinate. As a rule the solution flows back into the bladder with little difficulty. When the bladder is full of the solution, the patient voids it and the bladder is refilled. This is repeated two or three times or until about three pints of the solution have been used, always, however, with the utmost gentleness. Force is never required. We do not hesitate to carry the solution directly to the bladder, as the bladder is not affected by the gonococci, unless the prostate first becomes inflamed. The irrigations seem to lessen the danger of prostatitis and epididymitis, so when the organisms are deeper than the part medicated by the argyrol sealed in the anterior urethra we feel that urethro visical irrigation are called for. We never pass catheters or instruments of any kind in the treatment of acute urethral inflammations and rarely in the chronic cases. Especially do we regard with disapprobation the passage of sounds during the subsiding stage or chronic stage of gonorrhea. It seems there is nothing so likely to render the infection more difficult to cure than instrumentation when gonococci can be demonstrated or pus can be found in the first glass of urine. The best prophylactic measure against urethral stricture is to cure the infection with mild remedies. We have never seen a stricture caused by the sealing of argyrol in the urethra in the thousands of such treatments that we have administered. The irrigations of permanganate should be continued once or twice daily until the discharge ceases, and daily until the shreds and pus disappear. Occasionally later when the pus has diminished to a small amount, a solution of nitrate of silver, 1 to 8,000, may clear the mucous shreds more quickly than will the permanganate. It may occasionally, however, produce a recrudescence when employed too early. With this remedy, as with urethral irrigations, we emphasize the importance of not using strong solutions. If prostatic or other complications prevent the patient from emptying all of the permanganate solution from the bladder con-

siderable burning will be caused. In order to prevent this, we employ a boric-carbolic acid solution which will not cause pain when retained in the bladder. A handy way to prepare this solution is to mix boric acid with concentrated carbolic acid until it becomes a thick cream. Of this one drachm (four grams) to a quart of water or even a stronger solution may be employed. If we desire the nitrate of silver in addition, we use a saturated solution and of it add one, two or three minims to two quarts of the boric-carbolic solution with which it is not incompatible. Instead of tablets of potassium permanganate we use saturated solution of potassium permanganate and add a teaspoonful to two quarts of physiological salt solution. Having started the practice of medicine prejudiced against the Valentine irrigation method, we have gradually become so thoroughly convinced of its usefulness that we think the value of it alone more than equals the good from all other measures combined, as internal medication, injections, vaccine therapy, and mechanical devices. While all of these remedies have a well defined though limited field of usefulness, they are of secondary importance in the management of gonorrhea. In hyperacute conditions we wait a few days before beginning local treatment with irrigations and injections.

Urethral Injections.—A five per cent. solution of argyrol or argentide (silver iodide) affords the best remedy for urethral injections. The latter does not stain the clothing. Protargol, one-fourth to one-half per cent., is also useful. The patient should always cleanse the penis and urinate before taking the injections. The solution should be held in the urethra from five to fifteen minutes each time and may be administered from two to four times daily. As the discharge ceases or becomes largely mucoid, zinc sulphate in one-half to one per cent. solution rarely may be substituted for the above injections.

Internal Medication.—Oil of sandalwood or balsam of copaiba in five minim doses three or four times daily may be used to supplement the other remedies. The filled capsules should be placed in a closed vessel with formaldehyde gas for three to six hours to harden the gelatine, and prevent the capsules from dissolving in the stomach, and thus obviate the usual gastric disturbance. One drachm (four grams) of formalin on a sponge in a chewing gum jar with a ground glass stopper provide the necessary apparatus for the hardening. Further hardening comes with age, so the capsules may become too hard if kept for a long time. Urethral irrigations, copious water drinking, and temperate habits will cure the majority of acute infections. Urethral injections and vaccine therapy properly employed may hasten the cure; the latter, if it consists of colon bacilli and staphylococci as well as gonococci, will probably lessen the possibility of a chronic affection due to the former organisms.

The Treatment of Chronic Gonorrhea.—This differs little from the routine treatment of acute gonorrhea except that a painstaking search is made to discover the cause of the chronicity. If appropriate treatment has been administered and the acute condition passes into chronic, it usually means that the prostate gland, the seminal vesicles, or the urethral crypts and follicles act as the protecting foci and thus harbor the organisms and protect them from the remedial measures employed.

Massage of the prostate gland every other day—not in acute prostatitis, but in the chronic—is of great importance and becomes necessary in about seventy to ninety per cent. of chronic cases. In massaging the prostate, firm steady pressure should be exerted over each lateral lobe, devoting especial attention to the nodules that may be felt.

Localized inflammations in the urethral follicles, Cowper's glands, and the sinus pocularis not infrequently act as foci for persisting infection. Generally speaking it is vastly more difficult to rid the patient of staphylococci and colon bacilli than gonococci. This statement does not hold true in chronic gonorrheal seminal vesiculitis. The persistent watery discharge with light mucous shreds is usually due to staphylococci and colon bacilli intrenched in the prostate or some such focus.

Inflamed follicles, lacunae, glands, etc., should be incised or excised according to the conditions present. Among the most troublesome complications is a chronic gonorrheal inflammation of the seminal vesicles. For such an affection a five per cent. solution of argyrol may be injected every day or two by Belfield's method, or the seminal vesicles may be incised and drained by the Fuller operation.

The use of endoscopic applications in gonorrhea is rarely to be advised. The same may be said of dilatation of the urethra with the Kollmann dilator or sounds. While these instruments are of great value in other affections and in treating the sequelæ of gonorrhea, they should never be used when gonococci are demonstrable. Instillations of nitrate of silver may sometimes, though rarely, be employed.

Vaccine Therapy.—If employed in acute inflammation this will often hasten the cure though many times it will be of no great value. We should begin with medium size doses and gradually increase the amount until we start the immunizing processes. Patients can never get well of a fully established case of gonorrhea until they have become immune. Chronic affections respond less satisfactorily to vaccine therapy than do the acute infections. There seems to be little advantage in employing autogenous vaccines where the identity of the infecting organisms is correctly determined. In addition to the dominating gonococcus or catarrhal micrococcus we employ the colon bacillus and staphylococcus aureus, albus, and citreus because of the likelihood of these organisms becoming secondarily implanted and producing the persistent chronic affections so constantly observed.

Treatment with irrigations, injections, vaccine, and copious water drinking, should be continued for several weeks after the patient appears cured. He should also refrain from alcoholics and sexual indulgence until after we have reasonable assurance that the infection is probably eradicated. Certainty of the cure may be obtained by further time and dissipation tests, supplemented with the complement fixation test and urethral irritation and transplantation of the organisms from the prostate and seminal vesicles to the irritated urethra. This last named test is carried out as follows: The urethra is irritated by injecting a two per cent. solution of nitrate of silver and a few hours later, after the discharge has been established, the meatus is sealed with collodion and the prostate and seminal vesicles are massaged. The secretion thus expressed is retained for several hours in the irritated urethra. Repeated smears are examined during the next few days for gonococci which may be transferred in this manner from the deeper parts to the anterior urethra, where it is less difficult to demonstrate them.

The complement deviation test, when carried out by expert serologists, with polyvalent antigen, affords the most accurate method of detecting gonorrhea, especially in gonorrheal rheumatism and tubal infection. A positive reaction denotes the presence of recently active gonococci. If the infection is limited to the mucosa of the anterior urethra the reaction will be negative. A positive reaction may not become negative for two months after the gonococcic infection has been cured.

Treatment of Acute Gonorrhea in Women.—This consists in copious douches of permanganate of potassium, argyrol held for twenty to thirty minutes in the vagina, argyrol injections through the urethra into the bladder; copious water drinking; a restricted diet;

and no alcoholics or sexual intercourse. In the chronic form local applications of nitrate of silver to the cervix are usually necessary.

Vulvovaginitis in little girls, requires argyrol injections into the vagina once or twice daily, the drug being held there for thirty minutes; permanganate douches, and vaccine therapy.

The treatment of gonorrhea may be compared to dressing; each garment has a special field of usefulness, though some are more useful than others. Furthermore, much depends upon how the clothes are put on. If worn improperly one may have most expensive clothing and yet not appear well dressed; so one may apply good remedies and yet not administer good treatment. Effective treatment of gonorrhea requires both the correct and the timely application of the various remedial measures.

To paraphrase a literary simile we may say that there is as much difference between good treatment of gonorrhea and bad treatment, as there is between lightning and a lightning-bug.

Edgar G. Ballenger.

Gooch, Benjamin.—One of the most distinguished English surgeons of the eighteenth century. He practised his art at Shottisham, in the eastern part of England, and died about the year 1780, at an advanced age.

His published writings consist mainly of reports of cases which he himself observed, and consequently they still possess considerable value. The following are the titles of some of the more important of these writings: "Cases and Practical Remarks in Surgery; with sketches of machines of simple construction, easy application, and approved use," London, 1758 (2nd greatly enlarged edition in 1767); "A Practical Treatise on Wounds, and other chirurgical subjects, to which is prefixed a short historical account of the rise and progress of surgery," Norwich, 1767; and "Concerning Aneurysms of the Thigh," in Philosophical Transactions, 1775. A. H. B.

Goodell, William.—Born on the Island of Malta, in the Mediterranean, October 17, 1829. He received the degree of Doctor of Medicine from Jefferson Medical College, Philadelphia, in 1854. In 1865 he was appointed physician in charge of the Preston Retreat, and went to Philadelphia, making a specialty of obstetrics and diseases of women. He was Professor of Clinical Gynecology in the University of Pennsylvania. He died in 1894.

Dr. Goodell contributed many articles on obstetrical and gynecological topics to current medical literature. His work entitled "Lessons in Gynecology," however, was the most popular of all his writings. It was published in Philadelphia, first in 1879 and afterward in 1886. A. H. B.

Gordiacea.—An order of round worms. These animals are popularly known as "horse-hairs" or "horse-hair snakes" on account of their slender form. They are found in ditches and similar places where they swim or twine about aquatic plants. The larva usually passes through two hosts, insects as a rule. Several species of the genera *Gordius* and *Paragordius* have been found in the alimentary canal of man. See *Nematoda*. A. S. P.

Gordius.—A genus of round worms. *G. aquaticus*, the common "horse-hair snake," has sometimes been known to occur in the alimentary canal of man, where it caused various disturbances. See *Nematoda*.

A. S. P.

Gossypium.—Cotton. The plant *Gossypium herbaceum* L. and other species of *Gossypium* (fam. *Malvaceæ*). It yields to the materia medica, besides various fabrics of use in surgery, the following articles, which will be considered in order: cotton-root bark, cotton-seed oil, absorbent cotton, pyroxylin, collodion.

The specific identity and nativity of the different cotton plants are still subjects of controversy. Apparently some are of Asiatic, others of tropical American origin. As they agree in their properties, these questions are not here of practical importance. The plants are either herbs or shrubs, some reaching the dimensions of small trees, though the *tree cottons* proper of tropical America do not belong to this group at all. The cottons have alternate, stipulate, coarsely toothed or lobed leaves, and handsome, large, hollyhock-like flowers, white or yellow or changing with age to rose color. The fruit ("boll") is a large, ovoid capsule, bursting at maturity into three or four lobes.

Fig. 2815.—Cotton Boll, one-half natural size. (Baillon.)

The seeds are numerous, white, dark brown, or black, and completely concealed in the cotton-fiber, which consists of long white or tawny hairs developed from the seed coat. The plant abounds in mucilage, and its herbage and flowers have some domestic use for poultices, and the juice, as well as a decoction of its leaves, internally, as a demulcent.

Cotton-Root Bark, Gossypii Cortex.—"The dried bark of the root of *Gossypium herbaceum* L. and of other species of Gossypium" (U. S. P.). There are few official drugs so much in need of pharmacological study as this. There is the widest variation in the activity of different samples, apparently genuine, but of the causes of this variation we are ignorant. It has been claimed that the bark should be extracted in the recent state, also that the bark of the stem is frequently furnished instead of that of the root. It is by no means impossible that the age of the plant when the bark is collected, or its previous destruction by frost, affects its quality. Finally, it would seem that the bark of the shrubby tropical forms might be more active than that of our annual plant. The bark is thus described:

In thin, flexible bands or quilled pieces; outer surface brownish yellow, with slight, longitudinal ridges or meshes, small, black, circular dots, or short, transverse lines, and dull, brownish-orange patches, from the abrasion of the thin cork; inner surface whitish, of a silky luster, finely striate; bast fibers long, tough, and separable into papery layers; inodorous; taste very slightly acrid and faintly astringent.

The drug contains fat, resin, red coloring matter, and a small amount of tannin.

Our first knowledge of its properties came from its use among the negroes of the Southern United States for the production of criminal abortion. Speculation as to the source of their knowledge, and of its introduction from Africa, raises important questions as to

what species may have been there employed. Our slight knowledge of the drug's action is entirely clinical, and most of the testimony is against its activity, yet there is sufficient evidence that in some form it has been active as an abortifacient, parturifacient, and emmenagogue, acting much like ergot. The fluid extract is official, and the dose is ʒ ss. to ij (2.0–8.0).

Cotton-Seed Oil, Oleum Gossypii Seminis.—"A fixed oil expressed from the seeds of *Gossypium herbaceum* L. and of other species of *Gossypium*, and subsequently purified" (U. S. P.). The seeds are decorticated and lightly cooked before expression. The cake which remains is a most valuable fodder. The crude oil is largely used in the mechanical arts and for soap-making; but for domestic and pharmaceutical purposes it is purified by decantation after standing, boiling with water, and treatment with a weak alkali. The official oil is thus described: A pale yellow, oily liquid, without odor, and having a bland, nut-like taste. Specific gravity, 0.915 to 0.921 at 25° C. (77° F.). Very sparingly soluble in alcohol, but readily soluble in ether, chloroform, or carbon disulphide. On cooling the oil to a temperature below 12° C. (53.6° F.), particles of solid fat will separate. At about 0° to −5° C. (32° to 23° F)., the oil solidifies. When the oil is brought in contact with concentrated sulphuric acid, a dark reddish-brown color is instantly produced. If six grams of the oil be thoroughly shaken, in a test tube, for about two minutes, with a mixture of 1.5 grams of nitric acid and 0.5 gram of water, then heated in a bath of boiling water for not more than fifteen minutes, the oil will assume an orange or reddish-brown color, and, after standing for twelve hours at the ordinary temperature, will form a semi-solid mass. If 5 c.c. of the oil be thoroughly shaken, in a test tube, with 5 c.c. of an alcoholic solution of silver nitrate (made by dissolving 0.1 gram of silver nitrate in 10 c.c. of deodorized alcohol and adding two drops of nitric acid), and the mixture heated for about five minutes in a water bath, the oil will assume a red or reddish-brown color."

Cotton-seed oil consists of olein and palmatin. It is quite devoid of medicinal properties. If thoroughly purified, it is an excellent and delicious article of food, scarcely distinguishable by the average palate from olive oil, for the adulteration and substitution of which it is very largely employed. It in turn is adulterated with maize oil. It is also very largely used for the adulteration of lard. In the pharmacy it has many uses in taking the place of other more expensive and not superior oils.

Cotton, Absorbent, Purified Cotton, Gossypium Purificatum.—"The hairs of the seed of *Gossypium herbaceum* L. and of other species of *Gossypium*, freed from impurities and deprived of fatty matter" (U. S. P.). The cotton fiber is separated from the seeds, to which it is firmly adherent, by means of machines called gins, which, either by a series of circular saws revolving between the teeth of a comb-like guard or by cylinders which catch the cotton between them, pull or tear it away from them. It is then compressed in large bales and so exported. It consists entirely of long, thick-walled, collapsed, and spirally twisted tubes of glistening clearness, and high refractory power as seen under the microscope. It is nearly pure cellulose, with one or two per cent. of mineral matter, and has also a small amount of oily and resinous substances upon its surface—enough to make it repellent to water. For medical and surgical uses it is now beautifully purified from most of these impurities, and consists of more than ninety-nine per cent. of pure cellulose, $C_6H_{10}O_5$. The official purified cotton is thus characterized:

White, soft, fine filaments, appearing under the microscope as hollow, flattened, and twisted bands, spirally striate, and slightly thickened, at the edges; inodorous and tasteless; insoluble in ordinary solvents, but soluble in copper ammonium sulphate solution.

Purified cotton should be perfectly free from all visible impurities, and, on combustion, should not leave more than 0.8 per cent. of ash.

When purified cotton, previously compressed in the hand, is thus thrown on the surface of cold water, it should readily absorb the latter and sink, and the water should not acquire either an acid or an alkaline reaction (evidence of proper purification).

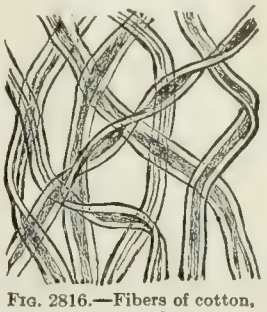


Fig. 2816.—Fibers of cotton, magnified.

Purified cotton is daily employed by the apothecary as a rapid filter or strainer for turbid solutions; it is also employed in the laboratory of the bacteriologist as a stopper for the tubes in which his "cultures" are made; but for this purpose it has to be specially "sterilized" by heat or other means. It is also used in the preparation of the aromatic "*Aquæ*" to distribute the essential oils over, in order to insure their most complete solution. It is also very extensively used, either with or without medication, as a surgical dressing. Dried from a solution of boric acid, 1 to 100; corrosive sublimate, 1 to 1,000; or carbolic acid 1 to 20; or impregnated with powdered iodoform, it can be rendered antiseptic; but such preparations need to be recently made, especially that with the carbolic acid. Exposure to a heat of something more than 100° C. (212° F.), for say half an hour, renders it practically aseptic, and in this condition it is very largely used as a dressing in antiseptic surgery. Nearly all surgical bandages, compresses, and gauze materials in this country are made from cotton.

The only preparation of purified cotton is gun-cotton, or pyroxylon. This is made by the action of nitric and sulphuric acids on absorbent cotton, the product being chiefly cellulose tetranitrate.

Collodium or Collodion is made by dissolving 4 parts of pyroxylon in a mixture of 75 parts of ether and 25 of alcohol. A flexible protective covering to the skin may be formed by painting with this solution and allowing it to evaporate. Henry H. Rusby.

Goulard, Thomas.—Is supposed to have been born at Saint-Nicholas-de-la-Grave, France, but the date of his birth is not known. According to the titles found in one of his writings, he was at one time professor of surgery at the College of Medicine in Montpelier, a member of the Royal Academy of Sciences at Montpelier, Lyons, and Toulouse, and of the Royal Academy of Surgeons of Paris. He was Surgeon-major of the military hospital at Montpelier and was pensioned by his King and the people of Languedoc for his remarkable work in lithotomy. He died in 1784.

Goulard was an early advocate of the use of bougies to prevent stricture of the urethra, but his name is preserved to us in the lead preparations called Goulard's extract and Goulard's cerate, introduced by him about 1760. His most important medical writing are as follows: "De la composition de bougies," 1751; "Traité des maladies de l'uréthre avec la composition des différentes espèces de bougies propres à les guérir radicalement," 1752. "Traité sur les effets des preparations de plomb, et principalement de l'extrait de saturne employé sous différentes formes et pour différentes maladies chirurgicales," 1760. E. L. J.

Goundou.—(Anákhré, Henpuye, *Gros Nez.*) A disease characterized by symmetrical ovoid bony

swellings on either side of the nose, involving chiefly the nasal processes of the superior maxillæ.

The disease was first described by MacAlister in 1882. It is seen mostly in the Niger country and on the west coast of Africa. A few cases have been reported in East Africa, Malaya, South America, and the West Indies. Some observers have suspected that it is a sequel of nasal myiasis; others that it is a sequel of syphilis or of yaws; others that it is, in certain tribes of negroes, a reversion to an ancestral peculiarity in the skeleton. None of these theories has any adequate foundation. Two cases in white persons have been reported. The etiology is unknown. The condition appears never to be congenital.

In most cases the development of the characteristic bony swellings has been preceded by persistent headache and a severe nasal catarrh, lasting several months. These symptoms subside entirely and are succeeded by the development of the bony swelling on each side of the nose. Each swelling is shaped like half an egg, the axis of the oval lying obliquely downward and outward from the bridge of the nose to the cheek. These swellings persist, and grow till they are sometimes post mortem as large as an orange, or larger, even obstructing in some cases the line of vision. The skin remains smooth and freely movable over the tumors. On section, either during life or postmortem, the periosteum covering the tumor is found to be of normal appearance and to strip easily off the underlying bone. The bone of which the tumor is composed consists of a compact outer layer and a cancellous or spongy interior, and appears to be the product of an osteoplastic periostitis involving chiefly the nasal process of the superior maxilla, to some extent the nasal bone, and sometimes the malar.

The *treatment* is surgical and consists in chiseling away the bony growth. Cases so treated have shown no signs of recurrence after several years.

J. F. Leys.

Gout.—The exact nature of gout is still unknown. One might begin a description of it as Sydenham did more than 200 years ago: "Either man will think that the nature of gout is wholly mysterious and incomprehensible or that a man like myself who has suffered from it thirty-four years must be of a slow and sluggish disposition not to have discovered something respecting the nature and treatment of a disease so peculiarly his own. Be this as it may, I will give a *bona fide* account of what I know. The difficulties and refinements relating to the disease itself and the methods of its cure, I will leave for time, the guide to truth, to clear up." Since Sydenham wrote, many hypotheses have been formulated to explain the disease but none have been fully substantiated. However, our knowledge of the malady has greatly increased, but its mystery has not yet been fathomed.

Gout has been recognized as a disease from the earliest times. It was well described by Hippocrates (350 B. C.). Five hundred years later Galen ascribed its origin to noxious substances as "black bile," "blood," or "phlegm" about the joints. He believed the tophi were produced by their consolidation.

In the middle ages, according to the prevailing theory, the disease originated from "tartar," which was supposed to come from wine that had been drunk and which formed incrustations about the joints, like those found in wine casks. This theory was disproved when Schule (1776) showed that tophi were composed of urates.

Gout has been thought contagious. This was the belief of Boerhaave. Cullen advocated a nervous origin for the malady. In 1848 Garrod's thesis on "The Blood and Urine in Gout, Rheumatism and Bright's Disease" established the existence of an excess of urate of sodium in the blood and ascribed to it a causative relationship to the malady. From that time to near the present a majority of pathologists and clinicians have regarded gout as due to an excess of uric acid in the blood, and they have described those prone to it in its typical or irregular forms as of the uric-acid diathesis.

As our clinical knowledge of gout is comparatively perfect, it seems best, therefore, to describe its symptoms first and to consider its nature, causation, prophylaxis, and treatment later. Cases of gout are clinically placed in three groups: (1) Acute gout; (2) chronic gout; (3) irregular gout.

Acute Gout.—Premonitory symptoms are commonly observed. They are usually those of gastric indigestion, such as flatulence, sourness of the stomach, a feeling of fulness in the epigastrium and constipation, or irritability of temper, restlessness at night, dull headache, or melancholia. Twinges of pain in the small joints of the feet and toes are often felt for several days before the acute attack occurs.

Acute gout commonly makes its onset in the early morning hours, the patient awakening with intense pain in the metatarso-phalangeal joint of one big toe, oftenest the right. The pain is severe but becomes more intense during the next two or three nights. It is described as a sensation of squeezing. The feeling is as if the toe were in a vice. Throbbing, burning, and sometimes lancinating pains, are also complained of. At first the veins about the affected part are unusually prominent. Soon, however, the joint swells uniformly and the skin becomes slightly red and glossy. It is exquisitely tender, so that even the weight of the bed-clothing is a source of increasing distress. The slightest motion of the joint also elicits a cry of anguish from the sufferer. Bodily temperature is increased, often only a little, sometimes to 102° or 103° F.

Often such attacks of podagra begin with a chill, or at least with chilly sensations and rise of temperature. After daybreak the pain subsides, fever lessens, and the patient may doze for a time. Although the intense pain is less, the swelling remains in the affected joint and it is kept immobile because of the pain which movements of it provoke. Toward night the symptoms again become more intense. So long as the attack lasts each night is made sleepless by an aggravation of the characteristic symptoms of the malady. Patients therefore become greatly wearied, even much debilitated by sleeplessness, suffering, and inability to maintain good nutrition, for appetite is lacking and digestion is impaired. An attack such as this lasts for from one to several weeks. Gradually the symptoms grow less intense, the swelling of the joint subsides, mobility returns, and often after an attack a patient will feel unusually well. Sometimes during convalescence the skin over the joint which has been affected peels off.

Attacks are frequently prolonged by one great toe after the other being involved or by other joints than those of the toes being attacked. Although the large toes are commonly first involved, the fingers, and later the large joints, may be as well.

The urine is frequently concentrated and deposits urates. Traces of albumin or sugar are also sometimes found in it.

Acute gout is apt to occur in the late winter and early spring. It recurs at variable intervals; it may be annually or at longer or shorter periods. Usually after several attacks it begins to recur more and more frequently and the individual's health becomes permanently impaired. It is extremely rare that only one attack occurs in a lifetime.

Chronic Gout.—Chronic gout results from several acute attacks. The joints which have been affected become permanently swollen or deformed by uratic deposits in the fibrous tissue about them, and are commonly stiffened and sometimes permanently immobile. Tophi, as these deposits of urate of sodium

are called, are also found upon cartilages, on synovial membranes, and the sheaths of tendons. The cartilages of the ear are affected with especial frequency. Nodules are also formed along the course of tendons on the back of the hands and feet. Uratic deposits within joints where they first take place are invisible and do not always cause noticeable enlargement of them, but rarely last long before the neighboring ligaments are involved. Intracapsular deposits can sometimes be detected by a grating noise produced when the rough surfaces are moved upon one another. When joints are impaired in usefulness the muscles which control them atrophy. In severe cases the skin over the tophi becomes necrotic, sloughs, and exposes the "chalk stones," permitting them to crumble or to be easily removed. This, however, rarely happens until the lesions are so extensive that in spite of the partial removal of a source of stiffness and deformity a renewed usefulness of the joint is impossible. Patients, typifying the severest cases, are helpless invalids and constant sufferers. In mild cases there is some stiffness at all times but there is not complete helplessness. Frequent acute exacerbations increase the pain which these patients suffer. They are accompanied by the usual symptoms of acute gout, and frequently are complicated by uremia, pleurisy, pericarditis, or other visceral lesions.

The joints are involved most frequently in the following order both in acute and chronic cases: metatarsal-phalangeal joints of the big toes, tarsal joints, ankles, knees, hands, and wrists. The elbows, shoulders, and hips are much less frequently involved and the jaws, larynx, and sternoclavicular joints least often.

The digestive disorders which so often precede and accompany acute attacks are present more or less constantly in chronic cases. Flatulence, acid indigestion, constipation, and gastric discomfort are the commonest symptoms of them. They are associated with headache, neuralgia, lassitude, mental depression, and irritability. Eczema and urticaria are common skin complications. In chronic gout the kidneys are usually involved and gradually become contracted, producing the symptoms which are peculiar to interstitial nephritis. The arteries are also liable to atheromatous changes and the heart to hypertrophy and ultimate enfeeblement.

The digestive and nervous symptoms are aggravated by an inability to take exercise, due to the joint deformities. Pain causes sleeplessness and exhaustion. Indigestion contributes to malnutrition, and it is usual for those who have chronic gout slowly to lose flesh and strength.

In spite of this chronic state of disease, surprising as it may seem, life is often prolonged into the period of old age. Indeed, it is usual for the malady to last for many years. Patients commonly show remarkable mental vigor.

Occasionally in the midst of acute articular gout or acute exacerbations of chronic gout, the acute arthritis suddenly disappears or greatly lessens, but is replaced by visceral complications. Such cases are often described as cases of retrocedent or suppressed gout. The visceral complications may be inflammations or other lesions of the bronchi, lungs, pleura, nasopharynx or larynx, of the stomach, intestines, heart, kidneys, brain, or peripheral nerves.

Epilepsy, delirium, and insanity are rarely a part of the disease. But neuralgias are common. Of these sciatica is the form most frequently observed. Gastralgia is also of frequent occurrence. It is associated with the usual indigestion of the affection. Of all the visceral complications of gout those of the circulatory system and kidneys are the most dangerous. Myocarditis is common. Endocarditis and pericarditis are of less frequent occurrence, but angina pectoris is often seen. Aortitis and aneurysms are other common circulatory affections. Functional irregularity of the heart and tachycardia are disturbances of frequent occurrence. Hypertrophy of the heart muscle is the rule in all chronic cases.

Interstitial nephritis develops sooner or later in those who suffer from chronic gout. It or uremia growing out of it is a common cause of death. Indeed, fatalities rarely result from uncomplicated gout.

Irregular Gout.—Irregular gout is difficult to describe and often to recognize with certainty. Some of the viscera or the skin may develop lesions which the gouty are known to be prone to, and their sequence may make a diagnosis possible or their nature may be recognized by reasoning by exclusion. Irregular gout is very much commoner than classical gout. It frequently occurs in the women in families in which acute and chronic gout attacks the men.

In early life urticaria is common in those having a gouty diathesis, or the lithemic state, and in late life chronic eczema is. Asthma, bronchitis, renal calculus, and diabetes mellitus are other maladies to which these same individuals are liable. Flatulent, acid indigestion and constipation associated with myalgias and neuralgias, with hemicrania or with mental depression or irritability are particularly significant of a tendency to the disease. Hot and itching feet at night and hot and itching eyeballs by day are common symptoms in women. Any of the various visceral lesions already mentioned may develop in those inclined to gout, although podagra or other articular evidence of the ailment may be wanting. Sooner or later the cardiovascular and renal disorders incident to chronic gout develop in a majority of those who suffer long with irregular gout. Iritis, glaucoma, and hemorrhagic retinitis are common complications of the malady.

Urine.—Between attacks of acute gout the urine may be normal. During an acute attack it is concentrated and diminished in amount. On standing, a pink or "brick-dust" sediment is thrown down. Although concentrated a diminished amount of uric acid is usually voided. When convalescence is established a moderate excess of this ingredient may be eliminated. In chronic gout the urine is commonly copious, of low specific gravity, and contains a diminished quantity of uric acid. However, not infrequently gouty men are found who habitually void normal quantities of uric acid. When interstitial nephritis exists the urine, besides being copious and of low specific gravity, contains small amounts of albumin and hyaline and fine granular casts.

Glycosuria occurs sometimes as a complication of gout. Sugar is rarely voided in large amounts in these cases. Moreover, by moderate dieting usually it is made readily to disappear from the urine. In a word such cases belong to the group of mild chronic diabetes. I have known attacks of acute gout to cease to recur after glycosuria developed.

Blood.—During acute attacks and while the disease is chronic an excess of urates can be demonstrated in the blood. But in the early stages of the disease, during the intervals between attacks, the blood is quite normal. Uric acid can be demonstrated in the serum of those who have gout by adding ten or twelve drops of acetic acid to a few cubic centimeters of blood or of serum obtained from a blister produced upon the skin. A thread must be immersed in this mixture of serum and acid for twenty-four or forty-eight hours, when it will be found to be covered with crystals of uric acid.

Diagnosis.—A diagnosis of acute gout usually can be made with ease, so distinct and characteristic are the symptoms. However, I have known a first attack to be mistaken for a trauma. But the development of symptoms characteristic of the course of the malady will correct such an error. It is rarely confused with acute articular rheumatism. In this last disease the large joints or numerous joints are involved

from the beginning, the temperature is usually higher, and the skin is bathed with perspiration.

The presence of tophi makes it possible to distinguish chronic gout from chronic rheumatism and other forms of chronic arthritis. The history of numerous acute attacks is also a help to a diagnosis.

Irregular gout is more difficult to recognize, but attention to the symptoms described above and to their interchangeability in different attacks in the same person and connection, commonly with characteristic digestive disturbances, makes a diagnosis possible.

Anatomical Changes.—The evidences of inflammation in the tissues involved are not different from those of other forms of inflammation, except that deposits of urates are observed with them. At first these deposits occur in the articular cartilages. They are seen as white dots or lines beneath the surface. Later they increase in size, coalesce, and produce destruction of the surface. The cartilages and capsules of joints, the fibrous tissue in bursæ, tendons, the periosteum, and the auricles are the structures in which tophi are oftenest found. The aorta is frequently thickened in spots by uratic deposits, as are sometimes the coronary arteries. An increase of fibrous tissue in the myocardium is also occasionally observable. The kidneys are commonly contracted and exhibit the conditions peculiar to interstitial nephritis. Lines of urates can be seen in many cases, both in the cortex and medullary portions of these organs. These deposits occur in parallel lines, partly in the uriniferous tubules, but mainly in the interstitial tissue between them. The liver is sometimes found in a condition of slight interstitial hyperplasia.

Theories as to Nature.—Although a clinical knowledge of gout has been possessed by physicians since the earliest times, its exact nature and cause are to-day unknown. A variety of hypothetical explanations have been offered, but none of them has as yet been established as correct. Garrod's theory was for many years accepted by the majority of the profession. According to him, gout is due to an excess of urates in the blood and fluids of the body, from which they are deposited in certain tissues because of a diminished alkalinity of them. The excess of urates, it has been supposed, is due in part to excessive production because of disturbed metabolism, and in part to imperfect elimination. That the renal epithelium has a power of selecting certain substances for elimination is a demonstrated fact, and it has been supposed by some that in gout it refuses to excrete uric acid in the normal or necessary amounts. There is no evidence that the blood or tissues in gout are less alkaline than in health but that there is an excess of urates in the blood must be admitted. Ebstein modified the theory of Garrod by advocating that an excess of uric acid was produced in muscles and bones because of a peculiar local metabolic anomaly which is usually inherited. The deposit of urates in cartilage and fibrous tissue he accounted for because of the naturally slow circulation of blood through them, which, when it contains an excess of uric acid, causes a cellular necrosis in those tissues. The necrosis always produces a local acidity, and the alkaline urates of the blood are then precipitated as comparatively insoluble acid urates.

The uric-acid theory has also been modified by the hypothetical explanation that uric acid is an intermediate product in the transformation of waste nitrogenous matter into urea, a transformation made in the liver, and that an excess of uric acid in the blood results from such a derangement of hepatic functions as causes the formation of a lessened amount of urea and a proportionately larger amount of uric acid. The observed coincidence of gout and digestive disturbances has given color to this theory. Of late, however, physiologists have become convinced that uric acid is not an intermediate step in the formation of urea from protein. Indeed recent researches (Kossel, Horbaczewski) have led physiological chemists to believe that uric acid is derived from nucleins and not from other constituents of cells. Still more recently it has been shown that hypoxanthine is formed by the activity of muscles and, probably by the action of a tissue enzyme, it is converted into uric acid as it passes out of the muscle into blood and lymph vessels. Barian in 1905 showed that this was the chief source of endogenous uric acid. But all endogenous nuclein is not excreted as uric acid, some escapes in the form of intermediate bodies and as urea.

Purin bodies occur in different tissues in different forms and relative proportions. Furthermore various cell-ferments have the power of modifying the various purin bodies and transforming them into simpler ones just as uric acid itself is converted by oxidase in the liver and other tissues into urea. Uric acid of exogenous origin is produced from the same constituents of food as is the endogenous from living tissues. It has been suggested that absence of some of these enzymes which convert purin bodies into uric acid and uric acid into urea may account for the excess of uric acid in the blood in gout.

Unfortunately for all these uric-acid theories gout cannot be produced experimentally by injecting uric acid into the blood or by preventing its elimination through the kidneys. Nor do the phenomena of the disease arise in other ailments, notably leukemia, in which uric acid often exists in the blood in quite as large quantities as in gout. Experiment affords us no evidence that toxic properties are possessed by uric acid even when it is introduced into the blood in much larger amounts than have ever been found in gout itself.

Another theory which has not in the last fifty years had so many supporters as the uric-acid hypothesis or so many as at the end of the eighteenth century, but which nevertheless at all times has had influential advocates, is the theory of its nervous origin. According to it, gout is due to a disturbed metabolism, a fault of the system in which the chemical balance is deranged. The metabolic processes are presumed to be under the control of the nervous system, therefore such a perversion of them as occurs in gout primarily must be due to a disturbance of nerve centers. Just what change takes place in the central nervous system is not conjectured. Those who believe in a nervous origin of gout base their faith chiefly upon the following points: (1) Its frequent inheritance. (2) The effect of psychic disturbances, such as anger or mental depression, in provoking its attacks. (3) A tendency to neuralgia and myalgia in such patients. (4) Influence of barometric changes. (5) Joint involvement, which is common to many nervous diseases. (6) Many neurotic manifestations observed in other members of the family in which gout appears.

In 1884 Gaucher discovered that the injection of xanthin and hypoxanthin into healthy animals caused changes in the structure of the kidneys, similar to those of interstitial nephritis. More recently others have confirmed these observations and found that the xanthin bases will produce various nervous phenomena as well as high arterial tension and ultimately arteriosclerosis.

Horbaczewski, who in 1891 showed that uric acid is derived from nuclein, has also gathered evidence to show that xanthin and hypoxanthin or the alloxuric bases are to blame for the phenomena of irregular gout of lithemia rather than the urates. It is true that uric acid in the form of biurate of sodium constitutes the tophi of gout and produces local deformities and sometimes inflammation, but in the form of a soluble alkaline, quadriurate in which Roberts believed it exists in the blood, it is not toxic. Roberts believed that uric acid circulated in the blood as a quadriurate but was deposited in tophi as a biurate. In recent

years it is denied that it exists in the blood either as uric acid or a quadriurate, but probably in some loose union with a protein molecule. Minkowski believes that it is in the form of neucleotin-phosphoric acid. The suggestion has been made that in gout uric acid is carried not by the usual protein molecule but by another or in some other than the usual combination in the molecule. However, all of this is theory and not at all adequately supported by facts.

Gout has so long been considered a disturbance of metabolism that most physicians do not appreciate that it has been suggested that gout is due to infection. The theories which have infection for a basis take it for granted that microbes in the intestinal tract either modify intestinal secretions or when the latter are otherwise modified produce as a result a toxin which is a cause of the phenomena of gout. However, as yet there is no adequate evidence that gout is an infectious disease.

Causative Conditions.—It is quite evident from this brief review of the leading hypotheses advanced to explain the causation of gout that we are to-day about as ignorant as our predecessors a century or two ago were. What knowledge we possess to-day is negative, that is, disproves theories that have been widely held. Nevertheless, much is known of the conditions under which gout is likely to arise. Heredity plays a large part in its production. According to Garrod seventy-five per cent. of all cases inherit the disease. Oftentimes the habits of families which their inherited environment produces also predispose them to it. But gout may be acquired as well as inherited. Acute and chronic gout are rarely seen in this country, but irregular gout is common and is increasing. Gout occurs oftenest in England, next in frequency in France and Holland, less in Germany and rarely elsewhere in Europe. Symptoms of it have been observed at all periods of life, but its onset occurs in much the largest proportion of cases between the thirtieth and fortieth years. Initial symptoms are extremely rare in infancy, childhood, and old age. Women are attacked less frequently than men, at least with the symptoms of prodagra and chronic gout. Insufficient exercise, and what amounts to the same thing, a deficient supply of oxygen, are important factors in creating a disposition to the ailment. A sedentary life causes the inhalation of relatively a small amount of oxygen. Shallow breathing, which is cultivated under the circumstances, lessens the vigor of the lymphatic and venous currents which carry off waste matters from the viscera, and causes a torpidity of liver and digestive organs. Lack of exercise also causes the same interference with vigorous metabolism in the voluntary muscles. When people live or work in overcrowded rooms they are sure to feel the need of oxygen. Virchow has laid stress upon the frequent production of tophi in the joints of the poor who live under these conditions. Since the earliest times it has been admitted that eating unduly large quantities of food will produce the ailment in many persons. Especially is this true of the use of large quantities of meats rich in extractives, or cooked with rich gravies and sauces. Although oftenest too much food, that which is too rich, and too little exercise together cause gout, rare cases have been observed in which an acute attack was provoked in those disposed to it by too little food and too much exercise. In these latter patients a lowering of vitality by underfeeding and overworking excited the ailment. The habitual use of fermented liquors is a most common and universally recognized cause of gout. It is difficult to explain the mode of action of these liquors. It is not merely the alcohol which they contain, for the users of distilled liquors are much less prone to the disease than are the users of fermented beverages. Nor is it an acid, nor sugar, nor, as far as we know, any one ingredient in beers and wines which makes the drinkers of them so liable to develop gout unless it is a purin body or bodies. Comparatively recently it has been shown that alcohol given with a definite quantity of purin bodies or nuclein will cause greater elimination of uric acid by the kidneys than occurs when no alcohol is given or when alcohol and a smaller quantity of purin bodies are given. It therefore seems probable that alcohol inhibits the transformation of uric acid into urea by oxidase. Often a few glasses of wine will awaken symptoms of the malady in those who are susceptible to it. It may be that the disturbances of digestion which overeating and the use of fermented liquors cause are more to blame than individual articles of food or beverages. Mental depression such as grief and anxiety or prolonged mental exertion are also frequent predisposing causes. They may help to produce their ill effects by making digestion slow and disturbing the functional power of the organs which play a part in it. It is well known that lead workers are especially liable to symptoms of gout as well as to arteriosclerosis and interstitial nephritis. This includes painters, plumbers, tinners, and others working with lead or lead products. Lindsay found that twenty-two and two-fifths per cent. of his 482 patients belonged to this class. Next to the lead workers come the beer drinkers which includes especially saloon men, brewers, and those in trades which lead to drinking.

Many of these conditions which predispose to the disease act together, that is, simultaneously upon individuals. Many of them are also the exciting causes of acute outbreaks of the ailment. Exposure to cold, great fatigue, anything which lowers the vitality for the moment may be an exciting cause for those who are susceptible.

Prophylaxis.—A knowledge of the conditions which dispose the gouty to attacks affords us a key to its prophylactic treatment. Good hygienic surroundings, daily sufficient exercise (often large amounts are required), moderate eating, and freedom from undue anxiety, worry, or mental labor, are the best prophylactic measures.

Treatment.—Little can be done to shorten acute attacks of gout, but the pain attending them may be lessened by suitable treatment, and a great deal can be done to prevent a recurrence of acute attacks by instituting a proper regimen.

It is impossible to remove the inherited fault of nutrition, but it is possible to retard the development of symptoms. Temperance must be taught as the cardinal rule of life, abstemiousness in eating, drinking, the enjoyments of the pleasures of life, or the inclination for mental work. Overeating, even the most moderate kind, must be avoided. A varied diet may be permitted, provided it includes foods which are simply prepared and easily digested, and provided they are eaten in moderate quantities.

When gout is fairly established, not only must temperance be insisted upon, but certain articles of diet must be forbidden. These are sweets, confections of all kinds, fats, articles cooked with much fat, game, and the richer meats, especially when dressed with rich sauces. Vegetables, rich in oxalates, ought also to be avoided by the gouty.

These patients should eat fairly varied foods and the diet should be well balanced, containing a normal proportion of albumin, carbohydrates, and fats; and the individual articles of food should be so prepared as to be most easily digested. Meat may be eaten moderately, but green vegetables, certain fats, and cereals, may be taken generously. The diet for those who are gouty must not be so restricted as to lessen their vitality. A milk diet has been urged as the best for the prevention of outbreaks of gout in those disposed to them; but milk, unless used in excessively large quantities, is not sufficiently nutritious; and while it may well be used as an important element of

food it should not be the only article taken by the gouty.

Soups should be forbidden when the symptoms of goutiness are clearly manifested, but they may be taken in small amounts by those inclined to this ailment. Whenever they are used, they should be entirely free from fats, and preferably should not be made with a meat stock. Eggs, oysters, and clams may also be eaten, but lobsters, crabs, and shrimps are not to be recommended. Most fish can be eaten without harm, especially such as bluefish, whitefish, perch, shad, bass, and trout; but fishes richer in fats and those that are smoked and salted, such as salmon mackerel, halibut, and cod, are not so wholesome. Rich sauces should always be avoided. Meat should be eaten not oftener than once daily, and generally roasted or broiled. Those which are most to be avoided are pork, veal, game, and salted or smoked meats. Fat should be used in very moderate amounts, except butter which can be used with a reasonable degree of freedom, and cream in moderation. Such carbohydrate foods as bread, rice, sago, tapioca, oatmeal, and cracked wheat may be eaten generously, but pastries, hot breads, pancakes, and other articles of a similar kind, which are liable to form doughy masses in the stomach during the period of gastric digestion, should be avoided.

Sugar is not wholesome for the gouty. Such vegetables as rhubarb, tomatoes, radishes, spinach, cabbage, and, if they cause flatulence, baked beans, should be avoided.

The following green vegetables may be used freely: peas, string beans, corn, potatoes, turnips, carrots, parsnips, celery and celery plant, cauliflower, artichokes, broccoli, salads, cucumbers, and egg plant. Of the fruits, the following are best adapted for the use of these patients: pears, apples, raspberries, blueberries, blackberries, and oranges; but grapes, bananas, prunes, strawberries, and melons are not so wholesome. Pickles and condiments are to be avoided at all times.

Eating between meals should not be permitted. Gouty patients should be taught to eat slowly and to masticate their food carefully.

Especially should those inclined to gout avoid eating a large variety of food at one meal. Simplicity in diet as well as temperance in eating must be taught them. The variety which we all crave should be furnished by changes in food from meal to meal and from day to day.

Although by clinicians red meats generally are forbidden those who have chronic gout, cases have been successfully treated upon an almost exclusive meat diet. Salisbury steak, a little lettuce or spinach, and stale bread, varied occasionally by chicken, squab, eggs, and fish, have constituted the entire list of foods of these patients. The uniformity of the food and the ease of its digestion have prevented abnormal fermentations in the gastrointestinal tract just as an exclusive milk diet will do. This is the secret of success in such cases. The analysis of white and red meat shows no material difference in composition or in the amount of purin bodies contained in them.

In the midst of acute attacks it is best to administer little of any kind of food. Milk is the best staple article and may be the only one. Gruels and eggs may also be eaten, and oranges and lemons may usually be permitted. During convalescence the "purin-free" diet, consisting of milk, dairy products such as butter and cheese, and eggs, and white bread and cereals can gradually be modified by adding to it spinach, lettuce, string and wax beans, cauliflower, and other garden leaves and fruits. The root vegetables should not be eaten until recovery is accomplished. A small amount of potatoes may be permitted, though an exception to this last statement.

Tea and coffee in small amounts and with no, or very little, sugar, may be used by those who are predisposed to gout, provided they have no acute symptoms of the disease or of indigestion; but if digestion is slow, or there are other symptoms of gout or goutiness, these beverages should be forbidden,

It is universally admitted that alcoholic beverages of all kinds are harmful. Even in very small amounts they will, not infrequently, provoke attacks of gout. The degree of tolerance of alcoholic beverages by those who are gouty is, of course, very variable. It is not necessary, in order to provoke gout, that these beverages should be taken to the point of intoxication. Indeed the occasional drunkard rarely develops symptoms of the disease, but it occurs most frequently in those who are habitual users of alcoholic beverages in moderate amounts. Ale, beer, and the sweet and the heavy wines are the beverages which are most apt to provoke the trouble. Of wines, the dry white wines and old Bordeaux have been found the least harmful. Although individuals vary in their susceptibility to the ill effects of alcoholic beverages, and although the different beverages vary in their potency to do harm, they should all be forbidden the gouty.

Patients who are gouty should drink water copiously in order that the kidneys may be made to act freely and that the waste matter may thus be washed out of the system. From five to eight glasses of good pure water should be drunk daily.

Many spring waters have been recommended as preventives of gout. It is probable that large quantities of water do more good by the physical presence of fluid in the blood-vessels and tissues than the various mineral ingredients which spring water may from time to time contain. There are three varieties of spring waters especially recommended for gout: First, those which are particularly pure and contain a minimum amount of mineral matter. Without doubt, their effect is a physical one. Second, the alkaline waters of which Vichy is a type. Alkalies well diluted, introduced into the blood, do seem to stimulate normal nutritive changes in the tissues of the body. The alkaline waters also have a beneficial effect upon the contents of the stomach, which are usually acid because of abnormal fermentation. Third, spring waters which contain iron, arsenic, and lithium. They are useful, especially the arsenical waters, for those gouty persons who have affections of the skin and bronchial mucous membranes. Many of the cases of gouty dyspepsia are helped by these waters. Royat, in France, may be regarded as a type of this group of mineral waters.

Recently the good effect of spring waters has been ascribed largely to radium emanation or radio-active substances contained in them instead of to chemical constituents but though many are radio-active the relationship of this property to good results obtained in gout has not been demonstrated.

Spring waters rich in sodium salts are not beneficial for the gouty, as these salts in unusual quantities in the blood hasten the precipitation of insoluble urates in joints or other tissues.

Hot mineral springs are resorted to by many who have chronic gout, for the purpose of bathing. Acute attacks are not benefited, but partially immobile joints with muscular atrophy are benefited. However, if patients have high arterial tension or hypertrophied hearts, hot baths must be avoided.

Exercise is essential in order to prevent gout and to avert repeated attacks in those who are prone to it. The amount of exercise required must be determined by each person. As a rule it must insure several hours of outdoor life each day and for at least a few minutes daily must be violent enough to provoke sweating. When repeated attacks have stiffened the joints and enfeebled patients, it must be more gentle. Walking, bicycling, horseback-riding are the best. These more gentle means of exercise can often be supplemented with benefit by daily or frequent massage. Of sports golf, which insures mild exercise for several hours out-

of-doors, is the best. The more violent games are rarely adapted to the gouty who are in middle life or have passed it.

Sufficient exercise should be taken daily, for the results thus obtained cannot be stored up at one time for future use.

In acute attacks physicians still resort, as Cullen recommended them to do, "to patience and flannels." Abortive treatment cannot be recommended. It has been attempted by strapping tightly the affected joint, applying ice to it, administering large doses of colchicum and sometimes morphine. Attacks have undoubtedly been stopped short in this way, but very dangerous symptoms have also followed the treatment, such as fainting and disorders of the heart. Most frequently soothing applications are made to the diseased joint, such as chloroform liniment or menthol (eight grams) in camphorated soap liniment (120 c.c.), or in an oil composed of Guaiacol 25 c.c., Ol. gaultheriæ 25 c.c., and Ol. olivæ, 50 c.c. Pomades with cacao butter and olive oil as bases are often used. To them may be added morphine, cocaine, belladonna, menthol, guaiacol, and other local anesthetics and analgesics.

After each local application has been made the affected foot or joint is wrapped thickly in flannel to protect it from cold and to promote local sweating. Rendu ("Traité de Therapeutique Appliqué," 1895, Paris) advises wet bandages which are gradually made colder until the diseased part is accustomed to ice-cold applications. The cold benumbs the sensibility, lessens pains and swelling, and shortens the duration of the malady. Like the so-called abortive treatment it must be used with care.

Blood-letting and blisters are no longer used in gout, but purgatives are. Calomel and jalap constitute a favorite prescription of English physicians. Certainly at the onset of an attack it is important to empty the gastrointestinal tract. A full dose of calomel followed in a few hours by a saline (the liquid citrate of magnesia is particularly eligible) does much good. At the same time the patient should abstain from food for from twenty-four to forty-eight hours but should drink water freely. When food is administered, and this should not be until copious bowel movements have insured the emptiness of the intestines, milk should be given.

Morphine or an opiate must be given sometimes in acute cases to promote sleep and to relieve pain when the latter is hard. Frequently the tincture of opium or the camphorated tincture are combined with the wine of colchicum partly to lessen pain and partly to prevent too much purgation. But of medicine colchicum is chiefly relied upon to relieve the acute symptoms. Twenty to twenty-five minims of the wine of colchicum root may be given three or four times daily. Instead of this preparation the tincture of the seeds of colchicum may be used. As soon as the sedative effects of the drug are obtained it should be given in smaller quantities and often can be discontinued. If used too long it will provoke nausea and excessive diarrhea. Indeed, a peculiar susceptibility to these effects of the drug makes its employment impossible in certain cases. Colchicum probably produces its good results by its sedative action upon the nervous and cardio-vascular systems and by helping elimination by its purgative properties. Colchicine can be substituted for the crude drugs and as good results can be obtained from it, it can be easily combined with morphine or the salicylates and agreeably administered in capsules.

Next to colchicum the salicylates are found useful. The salicylate of sodium is most used, but by some physicians the salicylate of lithium is preferred because, as some think, it is not desirable to add sodium to the fluids of the body since it forms with urates a less soluble salt than potassium and some other bases. A combination of the salicylate of sodium and bromide of lithium has proved useful to my patients. The salicylates are less certain in their effect than colchicum, but especially useful after colchicum is discontinued and in prolonged subacute attacks. It has been supposed that the salicylates aided the elimination of urates by making them more soluble but this is not proven. Doubtless their analgesic properties chiefly make them useful.

Alkalies also are used commonly. The best are the potassium and lithium salts. They are usually combined with colchicum or the salicylates. Originally they were given to hasten the elimination of uric acid by making soluble salts of it. Numerous other drugs in recent years have been tried for the same purpose, such as piperazin, lycetol, lysidin, and hexamethylenamin. While these and other drugs make urates more soluble in the laboratory there is not adequate proof that they do so in the human body, at least to an appreciable degree. Among the newer drugs which have gained some repute in the treatment of gout are urosin, sidonal and solural. The first is lithium quinate. It is given in doses of seven and one-half grains every one or two hours in acute gout which is said to quickly subside under its influence. Sidonal is a combination of piperazin and quinic acid. It is given in daily doses of one-half to one and one-half drams. Solural or nucleotin-phosphoric acid is given in doses of five to ten grains three or four times daily. All of these drugs are supposed to increase the elimination of uric acid. The doubt which prevails to-day in the minds of pathologists in regard to the pathogenic properties of uric acid makes their employment theoretically less urgent. Lithium has been shown to be useless so far as increasing the solubility of urates in the blood is concerned, for when administered by the mouth it forms insoluble compounds in the stomach and does not unite with the uric acid. However, I am convinced that lithium salts are beneficial in the indigestion of the gouty, probably because they unite with constituents of the contents of the stomach, and lessen their acidity and toxicity.

Guaiac is another remedy which is often employed in gout with benefit. Its mode of action cannot be satisfactorily explained. It proves most useful in subacute or mild acute cases. Oxygen inhalations, thyroid extract and orchitic and ovarian substance have been tried hoping that they would promote oxidation and afford relief, but have been of no benefit.

Chronic gout must be treated hygienically for the most part and acute exacerbations must be treated as acute gout is. The salicylates and alkalies are especially useful in these cases. Piperazin and similar drugs have been much used to dissolve tophi. The clinical results of their employment as they are described in periodical literature are conflicting. It and lysidin are also credited with the relief of pain.

Massage can be employed in chronic gout, and often after acute attacks, with benefit. It must, however, be applied with gentleness. It helps to reduce swelling, to make the joints more supple, and to strengthen the unused muscles. When joints are permanently deformed it is necessary by massage, electricity, and hydrotherapy to keep the atrophying muscles strong, in order that as much usefulness as possible may be preserved to the diseased part.

Little can be done to remove uratic deposits. Most attempts by local treatment are found to be more harmful than useful. Surgical interference is not to be recommended unless suppuration occurs near them (and it is a rare complication, not a part of the disease) or sloughing of the skin over them takes place; then the pus should be evacuated and any exposed urates scraped out and the wound treated as any other sluggish and infected wound would be.

A residence in a mild genial climate where an outdoor life can be had continuously is of great advantage in checking the progress of this ailment.

Often diet must be modified still further because of arteriosclerosis or contracted kidney and albuminuria. It must then be made even simpler. Red meats should not be used or, if at all, rarely. Indigestion and constipation must be carefully corrected or guarded against. Great pains must be taken to prevent fermentation in the gastrointestinal tract.

The iodides are frequently needed for their effect upon arteriosclerosis and atheroma. They may have to be given for weeks at a time. Potassium iodide is chiefly used, but Bouchard and Dyce Duckworth recommend the iodide of lithium. Nitroglycerin or the nitrites are needed sometimes for their temporary but more pronounced effects upon the arteries in lessening arterial tension.

In irregular gout chief reliance must be placed upon hygienic treatment. Various symptoms of the malady may for a time need medical treatment addressed to meet them. For instance, in the eczema of the gouty local applications are of benefit; but an abstemious, carefully regulated diet, the copious drinking of water, the maintenance of good elimination by the bowels, kidneys, and skin, and suitable exercise, are essential to success. The frequent restriction of foods to those that are "purin-free" for short intervals helps to maintain a feeling of well-being. It is probable that the simplicity of this diet and the small quantity eaten has as much to do with the feeling of well-being as that it is "purin-free."

For the headaches and neuralgias much can be done with the compounds of salicylic acid, acetphenetidin, acetanalidum, and similar drugs, but the relief is imperfect or transitory unless a suitable regimen is prescribed and maintained. Hemicrania can frequently be averted, when the temporal arteries begin to be tense and twinges of pain give warning of an attack, by a full dose of liquid citrate of magnesia.

Often such patients must change their business in order to obtain permanent relief, thereby avoiding the anxiety and confinement which a commercial or professional life necessitates. N. S. Davis.

De Graaf, Reignier.—Born in Schoonhaven, Holland, July 30, 1641. He studied medicine in Leyden, under François de le Boë, but received the

Fig. 2817.—Reignier De Graaf.

degree of Doctor of Medicine in 1665, at Angers, France. Upon his return to Holland, in 1666, he began the practice of his profession at Delft. His death occurred, August 17, 1673. He was an enthusiastic and careful anatomist.

In de Graaf's published writings on the genital organs of both the male and the female human being will be found many statements of new and important facts. Thus, for example, his name is connected with the structure called the "Graafian follicle." His separate monographs were collected and published under the title: "Opera omnia," Leyden, 1677.

A. H. B.

Von Graefe, Albrecht.—Born at Berlin, Prussia, May 22, 1828. He was the son of the celebrated surgeon, Carl Ferdinand von Graefe. He received the degree of Doctor of Medicine from the University

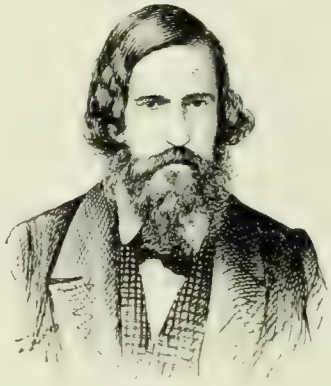


Fig. 2818.—Albrecht Von Graefe.

of Berlin in 1847. In 1848 he went to Prague, and upon the suggestion of Prof. Arlt, devoted himself chiefly to the study of ophthalmology. From Prague he visited, in succession, during the following two years, the clinics of Sichel and Desmarres in Paris, of the von Jaegers (father and son) in Vienna, of Bowman and Critchett in London, and of Donders in Utrecht. In 1850 he returned to Berlin, and began to practise as an eye surgeon. It was about this time that the use of the ophthalmoscope was first introduced by Helmholtz. von Graefe, who promptly recognized the great value of the instrument and was the first to put it to practical use, exclaimed: "Helmholtz has opened for us a new world!" In 1854 he founded the *Archiv für Ophthalmologie*, the first number issued containing almost exclusively articles which he himself had written. But Arlt and Donders soon joined him in the work of editing this periodical. In 1857 he was elected Extraordinary Professor of Ophthalmology, and in 1866 he was given the regular chair. His lecture room was crowded, not with students, but largely with practitioners who came from all parts of the world to listen to his teachings. His attractive personality, his earnestness of manner, the thoroughly scientific character of his subject matter, and the perfectly clear and simple language with which he presented his facts and ideas, fairly charmed his auditors. Unfortunately, von Graefe's bodily health was not equal to the task which he had set before himself. Frequent attacks of pleurisy interfered seriously with the continuity of his labors, and finally put an end to his life on July 20, 1870.

A. H. B.

Graefe, Alfred Karl.—Born in Martinskirchen, Germany, November 23, 1830. He was a cousin of Albrecht. After studying medicine at Halle, Heidelberg, Würzburg, Leipzig, and Prague, he received the doctor's degree in 1854 from the university of the first-named city. The subject of his graduating thesis was: "De canaliculorum lacrymalium natura." From 1855 to 1858 he acted as an assistant to his cousin, from whom indeed he received the major part of his training as an ophthalmologist. He managed, however, to spend a certain length of time in Paris during this period, with the object of working

under the instruction of Sichel and Desmarres, the leading ophthalmologists of that city. In 1858 he established himself in Halle as a Privatdozent, and organized a Clinic for Eye Diseases. In 1864 he was appointed Extraordinary Professor of Ophthalmology, and at the same time the university authorities assumed responsibility for the Clinic, which Graefe had up to that time supported at his own expense. In 1873 he was given the full professorship, and was appointed at the same time Director of the Ophthalmiatric Clinic. Still later, the title of "Geheimer Medicinal Rat" was conferred upon him. Between the years 1874 and 1880 Graefe, in association with Saemisch, of Bonn, published the great "Handbuch der gesammten Augenheilkunde," the part relating to the motor disturbances of the eye having been written by Graefe himself. Of his other contributions to ophthalmological literature some appeared in his cousin's *Archiv für Ophthalmologie*, others in *Fehender's klin. Monatsblätter*, and the remainder in various periodicals of a general (non-ophthalmological) character. The more important of Graefe's published writings bear the following titles: "Ueber Ischæmia retinæ;" "Ueber das Binocularsehen bei Schielenden;" "Ueber Cysticercus-Extraction aus den tiefsten Theilen des Auges, mit Construction eines Localisations-Ophthalmoskops;" "Ueber Wundbehandlung bei Augenoperationen;" "Ueber Extraction unreifer Staare;" "Ueber Enucleatio bulbi;" and "Ueber caustische und antiseptische Behandlung der Conjunctival-Entzündungen, mit besonderer Berücksichtigung der Blennorhœa neonatorum" (in Volkmann's Sammlung klinischer Vorträge, 1881). In 1892 Graefe, owing to ill health, resigned his professorship in the University of Halle, and took up his residence in Weimar. He died in the latter city on April 12, 1899.

While his career as an ophthalmologist was far less brilliant than that of his cousin Albrecht, Alfred takes high rank among the very clever men who composed the group of leaders of that specialty during the latter half of the nineteenth century.

A. H. B.

Graham, James Elliott.—One of the most distinguished Canadian physicians of the nineteenth century. Born at Brompton, Ontario, in 1847, Graham received his early education at Weston Grammar School and the Upper Canada College. He studied medicine at the Toronto School of Medicine and came out head of his year, receiving the University Gold Medal. The following year he became a resident physician at the Brooklyn City Hospital, and then, upon completion of his service in that institution, he went to Germany, intending to continue his medical studies in that country; but, in the meantime the Franco-Prussian war had broken out, and this led him to make a change in his plans. He applied for the position of surgeon in the Prussian army, without rank, and was promptly given the appointment. At the close of the war he went to Vienna, and availed himself fully of the great clinical advantages which that city affords. It was here that he laid the foundations of his wide knowledge of dermatology. From Vienna he went to London, and then, after pursuing his studies there for a few months, he returned to Toronto, where, at the close of 1872, he entered general practice. Three years later he was appointed Physician to the Toronto General Hospital, and at about the same time he became attached to the staff of the Toronto School of Medicine as Demonstrator of Anatomy and Microscopy. Gradually advancing from one position to another in the university, he was, upon the reorganization of the Medical Faculty of the University of Toronto in 1887, appointed Professor of Clinical Medicine and Medical Pathology, as well as Lecturer in Dermatology. Five years later he became full Professor of Medicine and Clinical Medicine. After 1893 he confined himself strictly, in private practice, to the rôle of a consultant in internal diseases. He died in 1899 at the relatively early age of fifty-two.

Graham was a very active contributor to current medical literature, as shown by the bibliography of his writings which was prepared by his nephew, Dr. H. J. Hamilton of Toronto. Of the fifty-seven essays enumerated in this list we may here mention only a very few, as follows: "Leprosy in New Brunswick," in the *Canadian Medical and Surgical Journal*, Montreal, 1883–1884; "Idiopathic Anæmia," in *Canadian Practitioner*, 1894; "Notes of a Case of Hepatico-Bronchial Fistula," in *Trans. of the Association of American Physicians*, Phila., 1886; "Notes of Two Cases of Acromegaly," in *Trans. of the Association of American Physicians*, Phila., 1890; "The Treatment of Typhoid Fever," in *Canadian Practitioner*, Toronto, 1891; "A Tumor of the Spinal Cord," in *International Clinics*, Phila., 1892; "Displacements of the Liver," in *Trans. of the Association of American Physicians*, Phila., 1895; and "Diseases of the Gall-Bladder and Ducts," in *American System of Practical Medicine*, 1898. (From data kindly furnished by Dr. A. Primrose of Toronto.)

A. H. B.

Gramineæ.—(The Grass Family.) This is doubtless, all things considered, the most important family of plants. The bamboos contribute most important building and structural material in the tropics, as well as considerable fiber material, which latter is also contributed by many other grasses. The uses of straw in this connection are too well known to require description. The grasses contribute by far the most important stock fodders, while the cereals constitute the most important part of human food and the principal source of alcoholic beverages and of alcohol itself. The sugar-cane, as well as sorghum, is a grass. An important fixed oil is obtained from Indian corn, which is also the chief source of glucose, and the importance of the starch yielded by it, as well as of those obtained from wheat, rye, rice, and barley, is apparent. Several important volatile oils are yielded by species of *Andropogon*. With one or two unimportant exceptions, poisonous properties are unknown in the family. Very few of the species are of distinct medicinal use, though Triticum is official, and ergot proceeds indirectly from rye.

Henry H. Rusby.

Granatum.—Pomegranate Bark. *Granati Cortex* or *Cortex Granati*. *Grenadier*. "The dried bark of the stem and root of *Punica granatum* L. (fam. *Punifaceæ*)," U. S. P.

This is a very beautiful shrub or small tree, producing a dense crown of glossy dark-green foliage, handsome deep-scarlet or crimson (in one form white) flowers, and the delicious fruit well known under this name. It is a native of Southwestern Asia and is now everywhere cultivated in tropical and subtropical countries. Some pharmacopœias require the root bark only, a judicious restriction (see *Constituents*). The French Codex recognizes also the flowers and fruit, and the rind of the latter, but all these are very inferior.

The bark occurs in quills several inches in length, and 0.5 to 2 cm. ($\frac{1}{5}$ to $\frac{4}{5}$ in.) in diameter, or in broken pieces of the same, the bark 1 to 3 mm. ($\frac{1}{25}$ to $\frac{1}{8}$ in.) thick; outer surface of the stem-bark exhibiting broad, shallow, rough, commonly short and reticulated, yellow fissures, alternating with less roughened, gray or slightly purplish-gray bands having sharp, lightly elevated margins, and usually more or less marked with small blackish spots of lichen; root bark, especially the thicker pieces, browner, less fissured, and more or less scaly and roughened; inner

surface finely striate, with some longitudinally elongated, blister-like elevations, and varying in color from pale greenish-yellow to cinnamon-brown; fracture short, granular, greenish-yellow, and showing a somewhat laminated stucture; taste astringent, very slightly bitter.

Constituents.—The important constituents of pomegranate bark are four alkaloids, together aggregating from one per cent. to three per cent. of the weight of the drug. Although evidence on this point is contradictory, it appears pretty well established that the

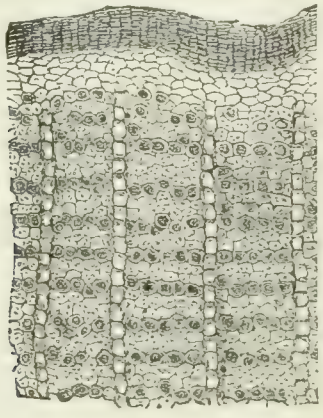


Fig. 2819.—Pomegranate Bark.

root bark contains about a half more alkaloid than the stem bark and that the barks of the white-flowered variety are richer than those of the red-flowered. There is a large amount of tannin (twenty per cent. or more), some mannit ("punicin" or "granatin"), much yellow coloring matter, and a very large amount (ten to fifteen per cent. or more) of ash. The tannic acid is interesting, being partly gallotannic and partly a form peculiar to this drug. The alkaloids exist for the most part as tannates. The most important is *pelletierine* or "punicine" ($C_8H_{15}NO$), which is a volatile liquid, soluble in water, alcohol, ether, and chloroform, and rapidly oxidizing, upon exposure, into a resin-like body. Its salts are crystalline. *Methylpelletierine* ($C_9H_{17}NO$) is similar, but somewhat less soluble in water. This alkaloid is more abundant in the root bark, the former more in the stem bark. The other alkaloids are *iso-pelletierine* and *pseudo-pelletierine* or "granatonine" ($C_9H_{13}NO.2H_2O$), the latter occurring in prismatic crystals, soluble in water, alcohol, and chloroform, and in nine parts of ether.

Pomegranate bark deteriorates rapidly on keeping. The alkaloids undergo a change, rendering them less soluble, soon after which they become decomposed. It is to be particularly noted that the commercial substances passing as pelletierine and its salts are in reality mixtures of all the alkaloids named above.

Action and Uses.—The important use of pomegranate bark is as a tænicide, its alkaloids being active. Opinions differ as to whether the parasite is killed or merely paralyzed by the drug. In any case, a brisk cathartic is required after its administration, owing to the strongly astringent effect of its tannin. Its astringent properties are often utilized for gargling and similar purposes and have been used internally, though the large doses thus used have frequently been followed by unpleasant emetic, and to some extent narcotic, effects. The official fluid extract is often employed, in doses of fl. ʒ ss.–iss. (2.0–6.0), and the powdered bark is given in corresponding doses. A very good method is to suspend the latter in mucilage. The ten per cent. decoction is the form probably most used, in wineglass doses. The tannate of the alkaloids (so-called "pelletierine-tannate") is not very largely employed in doses of gr. iij–vi. (0.2–0.4). This is after all the best form of administration since the inhibiting action of the free tannin of the bark is thus avoided.

The rind of the fruit (*Granati Fructus Cortex; Cortex Malicorii*) is largely utilized for its astringent properties. It contains rather more tannin than the bark, together with a still larger amount of gum, and is free from the alkaloids which, as stated above, often render the use of the bark as an astringent undesirable. This rind occurs in irregular, curved chip-like fragments, about two millimeters ($\frac{1}{12}$ in.) thick, externally brown, with a yellowish or sometimes reddish tint, finely tuberculate roughened, internally of a lighter or whitish color, marked with conchoidal depression indicating the position of the masses of seeds. The terminal pieces bear the thick, tubular cup-shaped remains of the calyx tube. The fracture is short, sharp, and granular. The drug is nearly odorless and strongly astringent.

Henry H. Rusby.

Granite State Spring.—Rockingham County, New Hampshire.

Post-office.—Atkinson.

Access.—Via the Boston and Maine Railroad to Atkinson, New Hampshire, thence about one-quarter of a mile to the Spring and bottling works.

The following analysis was made by W. French Smith:

One United States Gallon Contains

Solids.	Grains.
Calcium carbonate	0.94
Calcium sulphate	0.27
Sodium chloride	0.22
Iron and alumina	0.26
Silica	0.14
Organic matter "volatile"	1.70
Total	3.53

The organic matter is of a harmless nature. This is an exceptionally pure water, and of excellent quality for drinking purposes. The water is used largely in the manufacture of carbonated beverages.

Emma E. Walker.

Granulation Tissue.—Definition.—In crushing injuries, wounds involving the loss of considerable tissue, neglected wounds or those infected with pathogenic bacteria, or in wounds in which close coaptation by sutures is impossible, the healing process takes place by secondary intention, or, it is said, healing occurs by granulation. The origin of the latter expression is traceable to the appearance in such injured parts of minute pink or rosy elevations, the granulations; such surfaces are said to be granulating and the tissue forming the tiny nodules, as well as that below and about them, is granulation tissue. Granulations are peculiarly limited to exposed situations; similar processes of healing upon other surfaces, such as the intestinal canal and serous membranes, are very rarely if ever marked by elevations comparable to the granulations of healing wounds. This term consequently had its birth in the outward objective features of healing injuries of various sorts as well as locations.

The factors concerned in its production are the same as those which bring about repair anywhere as, for example, repair of the surgeon's simple incised wound which heals without infection or any other complication. The differences are largely quantitative and especially the varying ability to proliferate possessed by different tissues, epithelium, fibroblasts, and a few other cells proliferating

readily and extensively as compared with total or nearly entire inability to regenerate possessed by more highly specialized cells such as heart-muscle and nerve cells. Granulations are described, in the older works of surgery and pathology, as arising from the sectioned ends of bones, in abscesses undergoing "self-purification," chronic ulcers, fistulous openings, etc. The essential requisite seems to have been that they should occur either where they would be plainly visible or easily demonstrable or in such hidden locations where previous experience had proven their development. Necessarily this conception of granulation tissue was from the clinical viewpoint almost exclusively.

With the fuller knowledge of the process of inflammation, and especially of the regenerative changes connected with resolution, the designation granulation tissue has invaded topics of a more general character than those connected simply with surgical pathology. This tendency is, without doubt, due to the selection, by writers, of wound healing by secondary intention, as the type of regeneration or resolution in the inflammatory process; and because the cellular changes in resolution have more or less in common, no matter what the location is. The term granulation tissue has, therefore, by degrees acquired the significance of embryonal tissue. From this pathological conception, the chronic processes of inflammation, tuberculosis, syphilis, actinomycosis, leprosy, etc., in which proliferative changes predominate, acquired the group-name *granulomata*. There may be no granulations in the surgical sense in a gumma or actinomycotic growth, yet they are commonly described as made up of granulation tissue. The analogy between the granulation tissue of a healing wound and a deeply seated chronic inflammation such as a gumma of the liver or testicle, is a histologic one; the former possesses perceptible granulations, the latter a structure similar to such delicate and sometimes barely visible excrescences. Granulations do not, as a rule, develop in the granulomas, but they are obvious characteristics of all sorts of wounds.

That consideration of granulation tissue which maintains its parity to embryonal tissue and its inflammatory origin belongs to the general subject of inflammation (see *Inflammation*), whereas the following description deals solely with granulation tissue as it is met with clinically, with the structures that gained the name primarily.

Healthy Granulations.—The surface of open wounds after a few hours becomes covered over with a delicate pellucid, gray or whitish layer which slowly becomes thicker and finally resembles the buffy coat. Its formation takes place after the cessation of hemorrhage, although some clear or slightly blood-tinged fluid may ooze from spots on its surface or from the edges for some time. Exposure to the drying influences of the air causes this exudate to change into a compact, rather brittle crust that effectually protects the underlying tissue; it is often some shade of brown from the admixture of blood. The protection of wounds by dressings may lessen the formation of a crust and the fibrinous coating may remain thin and translucent. For a number of days there may be no change in the appearance of such defensive vestures. After a variable length of time, depending upon the anatomical location, the variety of tissue, the individual's age, and other factors, granulations arise. It is usually a number of days, from four to ten, before they attain macroscopic proportions.

When it was regarded as good surgical treatment to approximate the edges of the flaps with strips of adhesive, after amputation of an extremity, it was observed that granulations appeared earliest on the vascular soft parts and sooner on the sectioned cancellous than compact bone. If, after a certain period of repose, the dried blood clot of the exposed wound or the dressing of the more carefully protected wound be removed, minute pink points will be visible upon the paler tissue around. They mark the site of future granulations, whose development is easily followed by examination at intervals. The pink spots deepen in hue and others appear; they enlarge to blotches that have a bright ruddy aspect, and become elevated as small globular tuberosities. In *sensu strictu*, this is granulation tissue.

These small eminences vary in size and give the surface a decided granular appearance; they level the smaller irregularities of rough and lacerated injuries. The tissue that forms them is common to all chronic inflammations; it is embryonal tissue in process of cicatrix production. The elevations containing loops of newly proliferated blood-vessels have been explained by Hamilton upon the basis of lessened pressure; in this manner he would account for their absence in deeply seated morbid conditions. It is doubtful if altered conditions of pressure are the only agencies influencing their development.

Perfectly healthy granulations may vary in height and form, they may possess flat or rounded tops and a uniformity or irregularity in size may be observed. Double or compound granulations are described. Their consistence varies within narrow limits; possessed of broad bases these warty growths give the impression of firmly interwoven tissue with soft but not fluid contents. On removal of the covering exudate by gentle washing, a clean, moist or glazed surface, translucent and devoid of visible vessels is exposed. Although there is no distinctive color to healthy granulations, the more livid hues bespeak poor circulatory conditions. A faint pellicle with bluish zones that merge into the white of the adjacent skin marks the healing margins from which epithelization has already begun. Healthy granulations are extremely sensitive if they arise in tissues well supplied with nerves; others from such structures as compact bone and tendons are relatively insensative. When situated on a flat surface they seldom rise much above the level of the adjacent skin. The cells composing granulation tissue are those peculiar to chronic inflammation; however, in the average granulating wound there are probably a greater variety than in the usual deeply seated chronic inflammation. Our knowledge of the histology and histogenesis of the healing process is in the main derived from experimental work upon animals, nevertheless it is generally accepted that healthy human granulations may contain

Fig. 2820.—Injected Blood-vessels in the Granulation Tissue from an Experimental Injury of the Tongue of a Dog. The arteries have a greater tortuosity. Six days after injury. (Modified from Thoma.)

all varieties of leucocytes and all forms of fiber-producing cells; also red blood corpuscles, phagocytes, giant cells, budding blood-vessels, fibrin, bacteria, and an intercellular substance of altered fluid from the blood- and lymph vessels.

When foreign particles or objects rendered soluble by the digestive enzymes of cells with more than ordinary difficulty obtain lodgement or are incorporated in granulation tissue, endothelial leucocytes are found grouped about them as the so-called "foreign body giant cell." The list of such "foreign bodies" is a long one and mention need be made of simply the more important materials such as cholesterin crystals, keratinized epithelium, the crystals of fatty acids, fibrin, elastic, or other fibers and particles of bone, because such giant cells are erroneously thought indicative of tuberculosis.

The origin and fate of the so-called plasma cell, a cell of the lymphoblast series which may be very abundant in granulation tissue, have been subjects of a great deal of controversy, some idea of which may be obtained from the writings of Schridde, Councilman, Porcile, and Unna.

Pathological Granulations.—The extent to which, in a specific example, the exudative and retrogressive or degenerative changes exceed those of proliferation, depends upon many factors; chief among these are the stage of healing and the initial cause. It has long been recognized by surgeons that variations may occur in the general mode of healing, deviations from the normal that permit the use of such a pleonastic expression as pathological granulations. The luxuriant or exuberant granulations have been known by the laity immemorially as "proud flesh" and as altogether undesirable in a healing wound. The torpid or languid granulations and the spongy or fungous forms may so delay healing that there is an easy transition from granulation tissue to ulcers. Ulcers consist of granulation tissue when the macroscopic evidences of

Fig. 2821.—Organizing Granulation Tissue. The left edge represents the deeper part. The round cells are both mono- and polymorphonuclear leucocytes. There are many spindle-shaped fibroblasts. (Modified from Ribbert.)

proliferation attain the degree of distinct granulations; other ulcers, the seat of extensive necrosis and exudation, may not possess any proliferating tissue; such ulcers are not granulating. Over forty years ago Paget made the statement that "all the varieties in the aspect of granulating wounds and sores, which the practised eye can recognize as signs of deflection from the right way to healing, are so many instances of different diseases of the granulation substance, diseases not enough investigated, though of much interest in the study of both the healing process and the organization of new products in inflammation."

This complaint finds an echo in the claim made by Reinbach, who, states that he was unable to find in the literature at his command a single instance of researches of this character, and he adds that Ziegler also knew of none. Reinbach prefers to abandon the older nomenclature comprising such terms as fungous, spongy, erethistic, croupous, etc., for the general term pathological granulations.

Of these he recognizes two forms with several subordinate types: (1) The *luxuriant superficial granulation*, that is usually "self-purifying" and characteristic of acute processes, and (2) the *superficial chronic granulation*. The strictly torpid granulations she classifies with ulcers on account of the absence of formative tissue.

It may well be that the fibroblasts do not have the proper conditions for growth, the proper food, that they are unable to form fibers which will gradually contract and cicatrize or the tissue may be one relatively poor in such cells.

In some of the masses of granulation tissue called by the dermatologists "vegetating dermatoses" or "granuloma pyogenicum" the fungating masses appear to lie outside the corium as though through some small defect in the felt-like layer of fibers forming the corium a mass of proliferating vessels and of edematous granulation tissue had sprung forth. The chronicity of these lesions may be due to the relatively few fibroblasts they contain, to their location in a measure outside the body. As for the first form they are marked by the histological features that belong to the process of suppuration (see *Inflammation*). Quantities of bacteria occur—generally cocci that show no special arrangement—and at different levels the changes indicative of miliary or microscopic abscesses. Leucocytes swarm within such granulations and among them eosinophiles and mononuclear leucocytes are numerous. The capillary loops of the outer zones suffer some necrosis. Large amounts of plasma ooze out to form the fluid parts of the exudate which with dead cells and cells partly or totally dissolved by the digestive proteases of the polymorphonuclear leucocytes, forms the "pus" or other secretion of the "weeping sore." In spite of the exudative and destructive changes karyokinetic figures are numerous in the deeper portions in fibroblasts and endothelial cells, and the fibroblasts produce fibers and become connected in the usual way.

As examples of superficial chronic granulations, Reinbach mentions both the torpid granulations, which, however, show some signs of growth, and those covered with mottled and white patches caused by necrosis of the outermost parts. The first of these subdivisions, although very slow to heal, nevertheless contain vertical bands of fiber-forming cells. They often follow burns and constitute virtually lesions intermediate between granulation tissue and real ulcers. The second variety, covered by a fibrinous exudate in spots and by necrotic tissue, was described by Billroth as "croup of the granulations." Surgeons on meeting with these hindrances to the normal course of healing are inclined to suspect wound diphtheria, *i.e.* a true infection with the bacillus of diphtheria. However, such areas of necrosis superficially located upon otherwise healthy granulations may be caused by other non-pyogenic bacteria, for example, the *Bacillus coli*.

The fibrin upon these diseased granulations, commonly limited to the periphery, may extend to considerable depths; when the spots clinically are dark yellow and brown, the necrosis may be accompanied by practically no inflammatory changes. The protective covering of fibrin no doubt is a powerful aid in healing. The fibroblasts which produce the collagenous fibers, of white fibrous tissue, are said to find an excellent soil in fibrin, in fact to utilize it as a pabulum. Some support for this are (1) the related absence of other cells in some exudates largely fibrinous, of cells with digestive proteolytic ferments to bring about its disappearance, (2) the long persistence of fibrin in certain situations such as the large

serous cavities and (3) the huge amounts of tissue which may be formed in replacing fibrin or as it is sometimes inaptly expressed, in "organizing" the fibrin. Good examples of this are the heavy walls of empyema sacs.

A careful review of the work of Reinbach demonstrated quite clearly that the interference with the process of cicatrization in granulation tissue is due to the precipitation of fibrin either as a covering or amongs the cells to simple necrosis, or to that form of necrosis which with serous exudation or liquefaction is generally known as suppuration. His work is based upon the careful histologic examination of tissue removed from many conditions that were associated with granulating surfaces. There is urgent need of equally thorough bacteriologic examination of such diseased human granulation tissue, especially researches that would include the use of animals.

There is yet another fact that prevents normal cicatrization, and that is obstruction to the blood supply of the growing tissue. The obstruction is only partial, and without doubt in many instances is attributable to an arterial supply that is inadequate in the number of vessels or their total caliber. In other cases the action of morbid conditions more centrally located or dependency of the part leads to inefficient supply of blood. That an edema of granulation tissue may occur is well known; doubtless a deficiency in quality or quantity of nourishment is responsible for the occasional total failure of resolution. Briefly, granulation tissue may be the seat of extensive necrosis, edema, and suppurative or fibrinous inflammations as well as combinations of these processes. Other pathological conditions, such as hemorrhage and the various cellular degenerations, may arise, but generally only as minor and incidental changes. The causes of pathological granulations often are to be sought in the character of the primary lesion, rather than in secondary infection or the injury of healthy granulations. Infection at the time of injury is frequently responsible for subsequent difficulties in healing.

The Protective Qualities of Granulation Tissue.—It is well known that granulations bleed readily; slight trauma of any sort disturbs the unorganized tissue and lacerates the embryonal and sprouting capillaries. As for infection, many experiments have proven that in this respect granulation tissue constitutes a serviceable barrier. One of these was the now classical experiment of Billroth. He ascertained that no ill effects followed daily dressing of healthy and experimentally produced granulations of a dog's back with lint saturated with pus, whereas inoculating such animals with the same material caused death. This simple test was many years later followed by the extensive experimental study of Afanassieff, who in a more scientific manner and by exact bacteriologic technique verified the results of Billroth.

Granulations were produced upon many animals of different species, and upon them virulent cultures of such bacteria as the bacillus of anthrax and the *Vibrio metchnikovi* were carefully smeared with a thick platinum needle. The serum exuding from granulations so treated was examined from time to time, stained preparations and media inoculations being made also; the virulence of the resulting growths was examined; histologic examination of the granulation tissue for bacteria and the inflammatory changes was carried out, and animals were killed in order to ascertain if general infection had occurred. Ample control experiments were employed. He found that bacteria placed upon healthy granulations of animals did not penetrate, nor did general infection result. Inoculations made with recovered growths of the bacteria denoted an attenuation in virulence by the sojourn upon granulation tissue. Afanassieff was strongly inclined to look upon the protection afforded by the granulation tissue in the light of a vaccination. Such an explanation, however, is controverted by two facts. One of these is that local reactions in the granulation tissue were not observed with sufficient regularity in all animals to be in accord with the production of a bacterial immunity. Another fact is that Noetzel has repeated many of the experiments of Afanassieff and found that after bacteria were kept in contact with granulating wounds for many days the animals did not acquire any immunity.

It must be remembered that in granulation tissue mechanical obstacles exist to infection, such as the outward current of fluid from the vessels and the exceedingly slow circulation. Phagocytosis undoubtedly plays some part, although it may be that the ingested bacteria are no longer viable at the time of their incorporation. The extracellular destruction of the bacteria by the fluids present in granulation tissue (Afanassieff) or by enzymes, belongs to fundamental problems of immunity (see *Immunity*).

One cannot overlook the fact that when granulation tissue has formed, a defensive mechanism has been produced and its production is in response to external injury. But granulation tissue usually contains bacteria; especially frequent are the ordinary pyogenic forms.

Although resistant to bacterial infection, granulating wounds allow of the ready absorption of many soluble substances. Roux, Bonnet, Demarquay, Gorny, Maas, and Hack, and many others, have made experiments regarding this. Not all substances are absorbed with equal facility. The concentration of the solution, its chemical composition, the size of the granulating surface, and the character of the injury producing it, as well as the time contact is allowed, all influence the absorption. Granulating surfaces following burns and caustics are not so permeable as some others; absorption is more rapid from some healing wounds than from freshly cut surfaces. Experiments by Kahlenberg have shown that boron is present in the urine in a few minutes after boric or boracic acid is applied to the unbroken normal skin. It probably is absorbed with equal or even greater readiness from granulating surfaces. Apomorphine and curare are not readily absorbed, but carbolic acid diffuses with great facility. Various alkaloids such as strychnine, morphine, pilocarpine, cocaine, etc., have been used, and carmine, sodium sulpho-indigotate, iodoform, potassium iodide, sodium salicylate, as well as many other substances. Hack recovered ferrocyanide of potassium from the urine ten minutes after its application to a granulating surface, and Maas was able by spraying abscess cavities with a camphor solution, in a patient with vertebral caries and pyemia, to sustain the heart action sufficiently to allow operation. These and many other interesting and curious facts have been discovered about this phase of granulation tissue.

Cicatrization.—With healing of wounds by granulation a scar is formed that becomes paler as contraction takes place. Resolution in this form of inflammation is not marked by any peculiarities that distinguish it from cicatrization elsewhere. It is, however, customary to refer in this connection to the very deforming contractions that sometimes follow burns, but it is the location of the cicatrix rather than any special properties it possesses that marks it as singular. The loose subcutaneous adipose and areolar tissues allow scars to produce disfigurements that excite special interest on account of their exteriority. Similar malformations may occur in less exposed locations that are fully as interesting and as remarkable—for instance, the acquired dextrocardia and lesser dislocations of the heart that follow indurative processes of the neighboring viscera. They constitute excellent examples of the partial failure of inflammation as an adaptive process. The develop-

ment of keloids in scars might be cited as another instance in which abnormal resolution builds a growth, which, to the surgeon at least, must ever serve as a striking illustration of the failure of inflammation as an adaptive process. In contrast to these irregularities in resolution and fully as interesting, is the failure of granulation tissue to organize about certain fistulous passages and their openings that lead to foreign bodies, necrotic tissue, etc. These are the so-called "sequestrum granulations." The failure of cicatrization in these cases seems to indicate a better adaptation of the process of inflammation, as it occurs in granulation tissue, to meet the requirements.

E. R. Le Count.

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Granuloma.—*Definition.*—The term granuloma is at the present time used in a clinical sense to cover a certain group of inflammatory tumor-like growths rather than to define distinct pathological entities. It includes a number of inflammatory neoplasms composed in the main of granulation tissue of which the inciting agent is still unknown, and also a considerable number the inciting agent of which has been determined. The usage of the term tuberculous granuloma or syphilitic granuloma is still frequent in clinical writings, though the tendency is to classify the conditions under the lesions tuberculosis or syphilis rather than to include them under the old term which for many years was used as a synonym for a tumor. It was indeed not until after the publication of Virchow's great work on tumors that the distinction between the granulomata or inflammatory tumors and the true neoplasms was clearly felt and even within the past few years some unclassified new growths have been transferred from the granuloma group by the discovery of the specific agent. The term, however, is convenient and has been retained for practical reasons.

Classification.—The growth of a highly vascularized connective tissue always occurs in the repair following aseptic injury, with the exception of certain tissues, such as the cornea, where the vascularization is slight or absent. This aseptic granulation tissue is produced in small quantities if the edges of the wound are in contiguity and is rapidly replaced by firm fibrous tissue, forming a minimal scar which furnishes the ultimate repair. Bacteria play no part in this process.

A second form of inflammation of connective tissue leading to the formation of tumor-like masses of connective and vascular tissue is produced by the presence of foreign bodies. Such aseptic inflammation may be produced by fabrics accidentally left in a wound (Fig. 2822), by the presence of dirt or of considerable amounts of blood pigment which act as an irritant to the connective tissue, or even by irritating fluids, such as salvarsan, mercury salts, turpentine, etc. The lining wall of a chronic abscess such as occasionally occurs after the hypodermatic administration of alkaloids is composed of granulation tissue. The injection of hard paraffin, such as is now frequently made for prosthetic purposes, is also sometimes followed by a development of a considerable amount of inflammatory tissue of a granulomatous nature.

A third form of granuloma is due to the presence of infectious organisms. The exuberant growth of the ordinary granulation tissue is caused by the pathogenic organisms or at least is greatly stimulated by the toxins of these organisms. (See article on *Granulation Tissue* for further details.) The tubercle

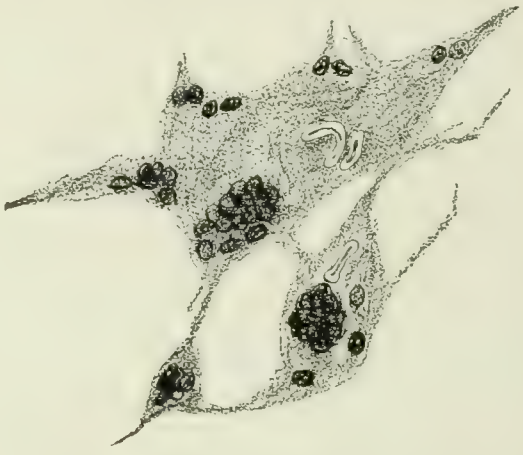

Fig. 2822.—Cotton Fibers Phagocyted by Giant Cells. Specimen was obtained from a sinus which had been packed with gauze.

bacillus, the lepra bacillus, the organism of syphilis, the organisms of glanders and actinomycosis, and the various types of yeast giving rise to blastomycosis, are all responsible for various types of granulomata. Certain tropical affections of the granulomatous type may also be included. Among these are the Peruvian wart and the Dehli boil, the latter produced by an organism resembling the Leishmania (J. H. Wright).

Simple Inflammatory Granulation Tissue.—This particular form of granulation tissue (for details see *Granulation Tissue*) varies a great deal in morphology, depending upon the conditions under which it is growing. The usual type is that seen in suppurating wounds or around sinuses which are kept open by

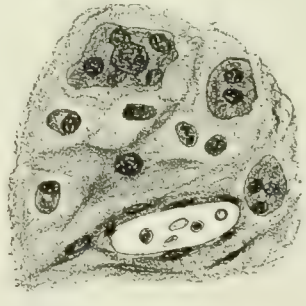

Fig. 2823.—Granulation Tissue from an Infected Wound, showing types of giant and plasma cells.

some foreign substance, as, for example, a fragment of bone deep in the body. The granulation tissue may be firm and composed largely of spindle cells with small, thick-walled vessels and a moderate number of infiltrating leucocytes. Under these circumstances only a few bacteria can be made out by specific stains. On the other hand the tissue may be extremely edematous, especially in the so-called exuberant granulations, and be formed of a jelly-like substance with a few spindle cells lying in the struc-

tures, and numerous erythrocytes, leucocytes and plasma cells. The capillaries are thin-walled with swollen endothelium, often showing white blood corpuscles in the process of diapedesis. The surface is covered with serum, fibrin and tissue débris. Usually many bacteria are present. Giant cells are occasionally found (Fig. 2823), and may lead to an incorrect diagnosis of tuberculosis; but usually these cells are not ofithe typical Langhans type (Fig. 2824), the nuclei being distributed evenly throughout the cell body. If the granulating surface or sinus is being

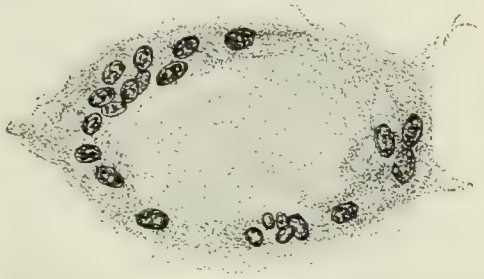

Fig. 2824.—Langhans Type of Giant Cells from Granulation Tissue Lining a Sinus Leading to Tuberculous Bone.

treated by local applications or dressings, foreign body giant cells are often present, owing to the fact that substances such as iodoform or other dusting powders are included in the tissues and act as irritants, giving rise to foreign body giant cells. Cotton fibers (Fig. 2822) also act in the same way. In closed abscesses with a wall of granulation tissue, giant cells are not infrequent, being due to the presence of fatty acids and cholesterin crystals which also act as foreign bodies and give rise to phagocytic giant cells, probably formed by fusion of the endothelial cells of the tissue. The granulomatous masses which form about the roots of decayed teeth or in a cavity due to the extraction of a tooth, may show giant cells (Fig. 2825) derived from the bone and periosteum. Some of the granulomata of the mouth, especially those of the tongue and pharnyx, may show a greater or less collection of plasma cells. (For further details see *Plasmomata.*)

When granulation tissue heals it contracts, the spindle cells lie much closer together, but the extreme

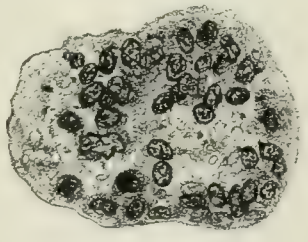

Fig. 2825.—Giant Cells from Granuloma of the Jaw, showing the epulide type in contradistinction to the Langhans type of giant cells shown in Fig. 2824.

vascularity may remain and the tissue resembles greatly a sarcoma or angioma. It is sometimes extremely difficult to draw any distinction between the two. The presence of bacteria is an important differential point. The number of mitoses in the spindle cells is greater in sarcoma than in granulation tissue. The blood-vessels are apt to be thicker walled in granulation tissue, and the stroma cells are not in such close relationship to the walls as in sarcoma. Fibrin is not frequent except in necrotic sarcomata, where hemorrhage has taken place in the tissues. If bleeding has occurred in the granulation tissue, altered blood pigment or hemosiderin is frequently taken up by the phagocytic cells and often imitates to an extraordinary degree the picture of a melanotic sarcoma. The differential in this case is made by the reaction for iron given by the hemosiderin; this reaction cannot be obtained from melanotic pigment of the tumor.

In the later stages the vessels disappear, the spindle cells shrink and are largely changed to collagen fibers and a firm, pale scar tissue is the result.

Leprosy.—In leprosy, tumors of a granulomatous nature may occur, due to the presence of the *B. leprœ*. This organism may produce a lesion very much like tuberculosis, the resemblance being particularly marked when the lesion has not undergone suppuration. Giant cells of the Langhans type are present and necrosis may occur and epithelioid cells may collect in large masses. It is usually perfectly easy to demonstrate abundant bacilli in the tissues, especially in the so-called lepra cells which are quite thickly stuffed with bacteria. The differential diagnosis between leprosy and tuberculosis must be based more upon the staining qualities of the *B. leprœ* or animal inoculations rather than upon the morphology of the lesions. The tubercle bacillus is much more resistant to acid or alcohol decolorization than the lepra bacillus, from which the color can be removed, in a short time by either of these agents.

Tuberculosis.—The tubercle bacillus may induce the formation of nodular granulomata which when they do not communicate with the surface retain a more or less characteristic morphology. When a tuberculous nodule has broken down and a fistula connecting with the skin has formed the pyogenic organisms give rise to extensive formation of granulation tissue of the ordinary type and as a rule typical tubercules are scanty, the slower tuberculous inflammation being overwhelmed by the rapid growth of infected granulation tissue. The lesions of tuberculosis are described elsewhere, but may be given in condensed form here. The inflammation is characterized by the production of tubercles or nodules of granulation tissue of characteristic appearance, being composed largely of large flat cells known as epithelioid cells, which are probably derived from the endothelium of the blood-vessels and tissue spaces. In addition to these cells, giant cells of the so-called Langhans type (Fig. 2824) are regularly present in all tuberculous granulomata and such cells are easily recognizable by the peripheral position of the nuclei. The tubercle is usually quite free from invasion by polymorphonuclear leucocytes and owing to its poor vascular supply it frequently undergoes necrosis. This necrosis usually begins in the center of the nodule while the periphery shows the tuberculous granulation tissue and the Langhans giant cells. It is possible also that the presence of the tubercle bacillus in the tissues may, because of the toxins produced, cause a growth of granulation tissue which, however, never possesses the characteristic giant cell tubercles; such lesions are not infrequent in the intestines, particularly in the caput coli, where the bacilli may be demonstrated though the lesion most resembles a simple chronic inflammation. Though no one would mistake tuberculous tissue for a tumor yet the differentiation of tuberculosis from certain forms of inflammation due to foreign bodies or from syphilis, is occasionally difficult. The demonstration of the tubercle bacillus by suitable stains is often not an easy matter and much time must be spent in searching a stained specimen in order to find a single organism. The presence of foreign bodies in granulation tissue gives rise to giant cells and to a certain extent to epithelioid proliferation, but here the differential diagnosis can easily be made if the giant cells are carefully examined, when it will be noted that many of them contain characteristic particles or fibers, usually dirt, wood splinters,

cotton or linen fibers, or silk, depending upon what material has been used in suturing or dressing the injured area, or whether ordinary inorganic material such as dirt has been ground into the wound in the course of the injury which produced the lesion.

The differential diagnosis between tuberculosis and syphilis is much more difficult. The diagnostic points are the greater number of giant cells in tuberculous tissue, the less extensive necrosis, and the perivascular infiltration which is absent in tuberculosis but present in syphilis. The result of serum tests such as the Wassermann or tuberculin reactions may be misleading as the patient may be suffering from both tuberculosis and syphilis.

Syphilis.—The specific organism of syphilis, the *Spirochæta pallida*, is capable of inducing small or large nodules of granulation tissue which may break down if occurring subdermally and form sinuses communicating with the external surface of the body. These then become infected with pyogenic organisms and an abundant growth of granulation tissue occurs. It is then quite impossible to determine whether the lesion is a simple chronic inflammation or syphilis. The closed granulomata or gummata are somewhat more typical but occasionally, especially in secondary lesions, a distinction between tuberculosis and syphilis may be impossible from a microscopical examination. In syphilis the nodules are formed of granulation tissue, usually rather extensive necrosis in the center. Toward the periphery the growth becomes firmer, forming a capsule. The blood-vessels usually show swollen endothelium with a dense perivascular infiltration with cells of lymphoid or plasma type. Giant cells are as a rule scanty, but may be abundant as in tuberculosis. They are of the Langhans type. The gross appearance of the necrotic center of the gumma is yellowish-green, while that of the tubercle is yellowish-gray. The gumma is less clearly outlined from the surrounding tissue than the tubercle, which is usually sharply demarcated.

Frambesia or Yaws (known also as Pian).—This is a chronic endemic infectious disease accompanied by nodular or ulcerative lesions, which occurs only in tropical countries. After a period of incubation which may be as much as six months the patient suffers from general symptoms, such as fever, headache, and pain; and these are followed by a squamous eruption. The eruption changes rapidly into a papular one, and the papules gradually alter into tumors which may reach a size of four or five or even ten centimeters in diameter. The lesion is largely in the epidermis, but a good deal of infiltration with plasma cells is seen in the subepithelial layers. When ulceration occurs there is a production of abundant granulation tissue without any specific characters. There are no important changes in the blood-vessels, in contradistinction to syphilis. A small spirochete-like parasite has been demonstrated in the epithelium, measuring seventeen to twenty micra and showing six to twenty turns. This organism has been named the *Treponema pertenue*. It closely resembles the *Spirochæta pallida*, though the coils are not so sharp as in the latter and the body is a little thicker. The organism stains without difficulty with the ordinary aniline stains.

Blastomycosis.—While a variety of yeasts, presumably saprophytic, are not infrequently found in the pus of chronic abscesses, two are of particular pathological importance. One, *Saccharomyces hominis*, attacks the deeper tissues and bone, giving rise to lesions which are frequenty confounded with syphilis and tuberculosis. The granulomatous nodules may ulcerate and be absorbed or large abscesses may form which finally break through the skin and leave fistulous tracts. The pus from the abscess contains a large number of yeast cells with double contour, which grow on ordinary culture media and are pathogenic for animals. The granulation tissue is rich in giant cells and eosinophiles. The former frequently enclose the parasites (Fig. 2826). A mycelium does not regularly develop in the cultures. The other type, *Oidiomycetum americana* is frequently found in the skin, but in later stages of the disease, which is very often fatal, may be present in all of the organs. The skin lesions are often multiple and resemble lupus or tuberculosis or even carcinoma. Sections of the nodules show an

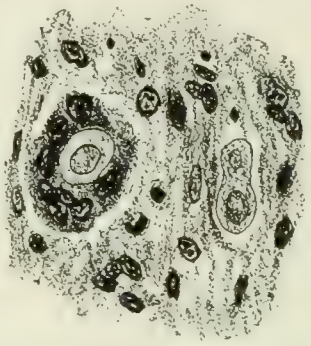

Fig. 2826.—Granulation Tissue from a Case of Blastomycosis. One of the parasites is enclosed in a giant cell.

abundant growth of granulation tissue containing many giant cells, eosinophiles, and plasma cells. The giant cells frequently contain phagocyted yeast cells. This type forms abundant mycelial filaments in cultures or artificial media.

Oriental Boil.—This type of granuloma is known under a variety of names, such as Bagdad boil, Aleppo boil, Biskra boil, and Delhi boil. The disease occurs chiefly in unprotected portions of the body in the form of a small reddish papule which, in the course of a few weeks, forms a painless circumscribed nodule with a smooth or slightly lobulated surface. In the course of several months it may measure two to three centimeters in diameter, and at this stage may undergo healing or, what is more frequent, the epidermis may soften with the formation of an ulcer. The central portion of the nodule breaks down and abundant granulation tissue is formed. The boils may be single or multiple. The ulcer gradually heals under the scab which forms, leaving a pigmented scar. In its acute phase there may be a good deal of pain locally, with such general symptoms as fever, headache, chills,

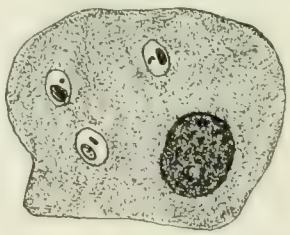

Fig. 2827.—Large Endothelial Cell Containing Three Parasites—*Leishmania tropica*—from a case of oriental boil.

etc. The regional lymph nodes may be involved in the inflammation. Microscopically the nodules are composed of granulation tissue containing large cells, usually with only one nucleus, which harbor the parasite. In the deeper layers plasma cells are found.

The parasite was first described by Wright (*Jour. Med. Res.*, 1908, x., 472) as a minute, oval or pyriform parasite, and was named by the discoverer *Helcosoma tropicum*. It is now, however, generally designated

Leishmania tropica, having been found to belong to the group of protozoan parasites first described by Leishman, which are closely related to the trypanosomes. In the tissues the parasite (Fig. 2827,) is usually found as a small oval or spherical body containing a nucleus and a small deeply staining rod-like structure, known as a blepharoplast. It averages about 1 to 1.5 micra in breadth and 3 micra in length. The organisms can be cultivated on suitable media and there develop flagella and undergo multiplication resembling that seen in trypanosomes. The diagnosis is made by staining smears from the ulcer by the Giemsa method and examining them with an oil immersion lens. The parasite will be found chiefly in the large mononuclear endothelial cells; more rarely, in the polymorphonuclear leucocytes.

Actinomycosis.—Another form of granuloma is that due to infection with the actinomycosis fungus (*Actinomyces bovis*). The granulation tissue formed does not differ greatly from the simple type due to pyogenic organisms except that epithelioid and eosinophile cells are not infrequent. The decisive points in the diagnosis, however, are the presence of minute, sulphur yellow granules, one millimeter or less in diameter, the ray fungus (Fig. 2828), found on cutting into or scraping the granulation tissue. When the disease is chronic and the history does not suggest the possibility of actinomycosis, the diagnosis may be very difficult, as the organisms present may be so few in number that they cannot be found except by the microscopical examination of many sections. This is especially true of the chronic suppurative sinuses which have undergone secondary infection, so that the picture is dominated by granulation tissue of the ordinary type due to irritation by pyogenic organisms.

Fig. 2828.—Actinomycosis. Specimen stained by Gram's method and eosin to show the clubbed ends of the parasites.

Madura Foot.—This disease, which is most frequently seen in India, though it occurs also in Africa and rarely in America, is a chronic granulomatous inflammation due to a fungus not unlike the *Actinomyces bovis*, except that the clubbing at the ends is not so marked. Both black and white forms of the fungus have been cultivated from the lesions, but for the exact classification of the organism further study will be necessary. The granuloma shows nothing specific except the masses of the fungus; it is composed of the ordinary granulation tissue structures, and numerous giant cells surround the fungi and especially the spores (conidia). The disease runs a long course and tends in some cases to spontaneous healing.

Glanders.—Infection with the *Bacillus mallei* which is frequently seen in horses occasionally occurs in man in the form of multiple nodules composed of granulation tissue. These nodules may suppurate or may break down and form ulcers. If the disease is chronic, a tissue suggesting that seen in tuberculosis may be produced by the proliferation of epithelioid cells, but giant cells are not found. The diagnosis is made by the isolation of the characteristic organism, either by injections of the tissue into male guinea-pigs in which case the testicle becomes enormously swollen and the organism can be isolated from this area, or by making cultures directly from one of the closed abscesses.

Rhinoscleroma.—Rhinoscleroma is an infectious disease attacking chiefly the mucous membrane of the nose and the skin around this opening, and leading to a thickening and closure of the nasal cavities. Very rarely the tracheal and bronchial mucous membranes are attacked. The growth appears in the form of firm nodules, bluish-red in color, which grow slowly and show no tendency to break down. Microscopical examination shows a richly cellular tissue with but little connective tissue with large swollen hyaline or Mikulicz cells which contain the specific bacilli (Fig. 2829). Plasma cells also are very abundant.

Fig. 2829.—Tissue from a Case of Rhinoscleroma, showing five Mikulicz's cells, and also numerous plasma cells and fibroblasts.

Sporotrichosis.—This is a rare, chronic infection of the skin by a group of organisms belonging to the fungi, *Sporotrichum beurmani*, *S. schenkii*, and *S. gougeroti*. The nodules consist of collections of epithelioid, round, and spindle cells which diffusely involve a limited area of the skin. Plasma cells are abundant and giant cells are not infrequent. The connective tissue and elastic fibers undergo a peculiar softening and swelling. Potassium iodide acts as a specific on the lesions, a fact which may be of diagnostic value when syphilis can be excluded. The fungus and the spores may occasionally be demonstrated in sections, but more usually only by culture. They are cylindrical threads of the same diameter throughout, branched, and containing egg-shaped or spherical spores which appear usually at the end or on the lateral aspects of the mycelial threads. They may be connected by a narrow pedicle or directly to the mycelium. The geographical distribution of the disease is very wide; numerous cases have been described from Europe, Africa, and North and South America. The lesion begins in the form of small nodules which gradually break down and suppurate. In the later stages ulceration spreads over long distances, undermining the skin without destroying it, though occasionally openings may be found from which pus is discharged. The general condition of the patient is not especially affected.

Mycosis Fungoides.—This form of granuloma is due to some unknown agent or possibly a poison which induces the formation in the skin of small tumors usually not over one to two centimeters in diameter. The borders of the new growths may be sharply defined or the structures may infiltrate the skin diffusely. Their appearance is often preceded by an eczema-like inflammation. The disease usually occurs in the upper portion of the body and the tumors are situated in the derma. Th mycotic tissue contains small and large lymphocytes, spindle-shaped connective-tissue cells, basophile cells, plasma cells, giant cells, usually not of the Langhans type, eosinophile cells, and many polymorphonuclear leucocytes. The blood-vessels are congested; the connective tissue not much altered. Occasionally, however, a marked edema occurs, due to thrombosis of the blood-vessels and hyaline masses in the walls. Ulceration of the epidermis may also occur with the production of the ordinary type of granulation tissue in addition to the specific mycotic type. In a certain number of cases classified clinically as mycosis fungoides metastases have been described in the internal organs.

An attempt has been made to classify the disease with leukemia. The general tendency at the present

time is to consider the metastasizing types as true sarcomata and to separate the leukemias as a separate group, since in mycosis fungoides, although there is occasionally a marked eosinophilia, other blood changes are not constant.

Verruga Peruviana.—This disease which occurs in a limited district on the west coast of South America is characterized by an eruption on the skin of the extremities and shoulders, and occasionally on the mucous membranes of the throat and mouth. The granuloma commences as a small circumscribed wheal, more apparent to the touch than to the sight, the surface of which shows a reddish tint. As it grows larger it may show a papillary form and be either uni- or multilobular, or it may vesiculate or suppurate. The smaller nodules often regress; the larger ones do so less frequently. The new growth lies in the derma and is composed of connective-tissue cells of various sizes and shapes, chiefly spindle or oval, while near the periphery large edematous cells occur, the so-called verruca cells. Small cells with coarse granules which take the basic stains, the so-called "mast-cells," are often abundant. Small hemorrhages and exudations of polymorphonuclear, leucocytes, lymphocytes and phagocytic cells containing crystals of hematoidin are not infrequent. Verruga peruviana has been transmitted by its virus to monkeys and rabbits, although no specific parasite has been isolated. The Wassermann reaction was negative in the cases examined by Strong (*J. A. M. A.*, 1913, lxi., 1713) with one exception, showing that there is no relation between this disease and syphilis. In the mild types of the disease, which comprise the greater portion of the cases, there is moderate fever with slight anemia, but in more severe cases the fever is high, and is accompanied by lassitude, malaise, pains in the joints, and marked anemia.

This review of the granulomata makes no pretense of completeness. Readers who desire additional information are referred to the individual subjects, such as tuberculosis, syphilis, etc. Further details may be found in Delafield and Prudden: Text-book of Pathology, 9th edition, 1911; Aschoff: Pathologische Anatomie, 3d edition, 1913; and, especially, in Kolle und Wassermann, Handbuch der pathogenen Mikroorganismen, volumes V. and VII., 2d edition, 1913.

F. C. Wood.

Granuloma Annulare.—*Synonyms:* Ringed Eruption (Tilbury Fox), Lichen Annularis (Galloway), Eruption Circinée Chronique de la Main (Dubreuilh), Néoplasie Circinée et Nodulaire des Extrémités (Brocq), Tumores benigni Sarcoidei Cutis (Rasch, Gregersen, and Galewski).

Definition.—A well defined, somewhat rare disease of the skin first described by Tilbury Fox in 1895,[1] and since reported under various names by various observers. In 1902 Radcliff-Crocker[2] reported four cases which he called granuloma annulare and while "granuloma" as now used is inapplicable to this disease, it is the name under which it is best known, and none better has been adopted. It consists of a ringed or semicircular, elevated, whitish or pinkish eruption, most frequently seen on the extremities without marked subjective symptoms and pursuing a chronic course.

Symptoms.—The disease usually begins insidiously, although cases have been reported in which it is thought to have appeared as abruptly as do urticarial lesions. The first intimation is the appearance of a nodule or a cluster of wart-like tubercles of a whitish, semi-translucent color, and without any marked itching or tenderness, occasionally there is slight itching, but throughout the whole course of the disease sensory disturbances are entirely absent or of a mild nature. As the eruption develops the nodules either extend at the margin, leaving a smooth, cyanotic, apparently depressed central area, or the lesions unite with adjacent nodules as they appear, in the form of a ring. Again, they first make their appearance in groups or clusters, which unite, forming the elevated, whitish, ringed or horseshoe-shaped eruption, which is so strikingly characteristic of the disease. When developed, these rings vary in size from one to five centimeters or larger. In shape they also vary, the ring, sometimes ncomplete, forms horseshoe or crescentic lesions,

Fig. 2830.—Granuloma Annulare of the Dorsum of the Foot. (After J. L. Bunch, Brit. Journal of Dermatology.)

again, the individual nodules may be grouped into festoons. Aside from the shape of the lesions the color is the most notable feature; the whitish, ivory colored, elevated lesions are accentuated by a pinkish areola and enclosing a livid, violaceous, sometimes atrophic central area. While the eruption is elevated as in urticaria, on palpation it is found to be deep-seated, which may also be shown on stretching the skin. The number of lesions present is usually small, being limited to from one or two to a half dozen; and while they are for the most part restricted to a certain area, cases are reported by Jadassohn[3] and Graham Little[4] in which the distribution is more generalized.

The course of the disease is always slow, several weeks or months being required for the evolution of the eruption, which may remain with but slight changes for many months or years. Untreated there seems to be little or no tendency for spontaneous involution to take place, although Sequira[5] and Jadassohn[3] report cases in which recovery took place without treatment.

While the hands are most frequently affected the disease may appear on various parts of the body. Thus Graham Little[4] found in an exhaustive study of forty-nine cases, which he thought belonged to this group, reported by various authors up to January, 1908, that the dorsum of the fingers and wrists were the parts of predilection, next in frequency came the feet, ankles, neck, elbows, knees, and buttocks. It seldom is seen on the face or scalp, although Pringle[6] observed a case in which the disease occurred on the face, neck, scalp, and wrist. The eruption may be either unilateral or symmetrical in distribution.

Unlike pernio, for which the disease might possibly be mistaken, granuloma annulare occurs most frequently during the summer months. The age of the cases reported varies from eighteen months to fifty-five years. The sexes are about equally affected. The disease seems to be encountered less frequently in America than in Europe, while most cases have been observed in England and France.

Histopathology.—The main pathological changes occur in the deeper parts of the corium, the epidermis often being but slightly affected. Thus the only

histological change recorded in Dubruilh's cases[7] was a diffuse cell infiltration in the middle zone of the corium; Galloway[8] reported cell infiltration in cutis with slight destruction of connective tissue. In Radcliffe-Crocker's cases[2] a thickened rete, sweat coils infiltrated with a dense cell mass in cutis were observed. Graham Little's findings[4] were fairly uniform, consisting in some instances of a moderate increase in thickness of the corneal and granular strata of the epidermis. In other cases the epidermis was normal. As in previous reports the most notable changes were found in the corium which increased from above downward, being slight in the subpapillary zone and limited to a moderate degree of cell infiltration, which, again, was wholly absent in some cases. This infiltration became more marked, however, as one proceeded downward, consisting in the middle and lowest parts of the derma of an accumulation of cells arranged in clumps which form the tumor mass. In these nodular masses there was an absence in some of the sections of elastic and connective-tissue fibers—or if present they were fragmentary. Besides these nodular accumulations of cells, the coil glands, hair-follicles, and blood-vessels were involved with apparently the same cell formation. The sweat coils were dilated and with the blood-vessels sometimes radiated from cell masses or extended upward in bands toward the surface. Furthermore there were a few cells scattered between the fascicles of the connective and elastic fibers in the adjacent parts. With a higher power the cells were seen to be made up chiefly of large mononuclears, larger than a leucocyte, staining vividly with nuclear dyes, but without the protoplasmic envelope of plasma cells, together with numerous spindle and pear-shaped cells indistinguishable from connective-tissue corpuscles. A few epithelioid and mast cells were also seen. In many sections the blood-vessels were thickened and some were obliterated apparently by endarteritis. Later in the course of the disease foci of destruction were observed in the central area of the nodular cell masses which contained only fragmentary elastic and collagen tissue lying between cells less closely packed. In the hypoderm a diffuse cell infiltration involved the fatty zone, which in some places was fibrotic over considerable areas. More recently Define[9] has for the most part confirmed these findings in a case observed in Italy.

Etiology.—It has been suggested that the season of the year has some bearing on the cause of the disease. The involvement of the sudoriparous glands during warm weather, when they are most active, has been mentioned as of etiological significance. At first the disease was associated with lupus erythematosus and it has been suggested by Crocker, Darrier, and Little that further study may show that it is allied to the tuberculides. Galewsky's[10] case did not react to tuberculin. Nothing is definitely known, however, as to its cause.

Diagnosis.—The diseases most liable to be mistaken for granuloma annulare are: chronic urticaria, erythema perstans, pernio, keloid, and lichen planus (annularis). The absence of subjective symptoms, the chronic course and limited area involved, would exclude the first named, while erythema perstans is not itself sufficiently understood to be regarded as a well-defined affection. The season of the year, together with the smarting and itching accompanying chilblains, would enable one to exclude this affection. More difficulty might be experienced in differentiating between granuloma annulare and lichen planus when the latter occurs over a limited area. The sensation of itching in lichen, its shiny, smooth, slightly scaly surface would serve to differentiate it, and a histological examination would show a less deep-seated involvement of the derma than is observed in granuloma annulare. This with the absence of the nodular cell masses and the thickened epidermic strata found in lichen would give ample differential features.

Treatment.—Of the various kinds of treatment, local applications of salicylic acid, tar, resorcin, thiosinamin, and ichthyol have been most successful. Sometimes the lesions disappear readily under slight influences, at other times they are more obstinate. Jadassohn[3] thinks the internal administration of arsenic more efficacious than external measures, while in most cases internal medication seems unnecessary. In one or two cases a biopsy made for the purpose of study and the bandages subsequently applied, were followed by the disappearance of the lesions thus covered. Salicylic acid, two to ten per cent., either in the form of a plaster or incorporated in an ointment of ichthyol or resorcin, has proved successful in many cases. The Röntgen rays have also been employed with favorable results. When the general health is impaired, as in some cases reported, iron, a generous dietary and fresh air may be necessary to improve the general health, thus strengthening the natural resistance of the patient.

William Thomas Corlett.

References.

1. Fox, T. Colcott: Brit. Jour. Derm., 1895, p. 91.
Hutchinson, Jonathan: *Ibid.* vol. i., p. 10, 1888, reported four cases in adult of a peculiar eruption of the hands and feet, which he called "Symmetrical Purple Congestion of the Skin in Patches, with Induration." These cases were in adult men: two of advanced age, the subjects of gout. This may account for the lividity described. As no histological studies were made it is difficult to determine whether or not they are allied to the cases subsequently reported and now called Granuloma Annulare.
2. Crocker, Radcliffe: *Ibid.*, 1902, p. 1.
3. Jadassohn, J.: Quoted from Graham Little, Brit. Jour. Derm., 1908.
4. Little, Graham: *Ibid.*, p. 47, *et seq.*
5. Sequira, J. H.: *Ibid.*, 1902, p. 270.
6. Pringle, J. J.: *Ibid.*, 1899, p. 435.
7. Dubreuilh, Wm.: Quoted by Graham Little, *loc. cit.*
8. Galloway, James.: *Ibid.*, 1899, p. 221.
9. Define, Giacomo: Abstracted in Annal, de derm. et de syph., 1913, p. 111.
10. Galewsky, E.: Ikonographia Derm., 1903, Fisc. III.

Grape.—(Including *Raisin*, or *Uva passa.*) The genus *Vitis* Tourn. (fam. *Vitaceæ*) comprises about thirty species of Vine, a number of which, either in their improved forms, or as hybrids, contribute our grapes. The young leaves, tendrils, and green fruit of the vine are sour and astringent, containing *tartaric, malic,* and other fruit *acids* or their salts; *tannic acid, quercetin, quercitrin,* etc., sugar, gum, and several earthy and alkaline bases. They are more or less employed in Europe in the form of "teas" or syrups as domestic remedies. The juice of one particularly sour variety expressed from the green fruit, and known as *verjus,* is used to make a flavoring and refreshing syrup. The sap of the stems has also been employed. Ripe grapes, and especially raisins, are much sweeter, containing from ten to forty per cent. of *sugars* (*dextrose, levulose, inosite*) besides the acids, salts, etc., above mentioned. Still these are more or less employed for the same purposes as the herbage. Their medicinal virtues are very unimportant.

From the ripe fruit of the European vine, *Vitis vinifera* L., raisins, and from one of its varieties the Greek, Zante, or English "currants" are made merely by careful drying. Raisins are slightly laxative, like figs and other dried sweet fruits, and they have a peculiar power in imparting flavor.

Henry H. Rusby.

Grape Sugar.—See *Dextrose.*

Grasse.—A French town of 15,000 inhabitants, is eleven miles north of Cannes, from which it is reached

by railway in forty minutes, and also by direct railway from Nice. This resort of the Riviera was brought especially to public notice by the visit of the Queen of England in the spring of 1891. It is very picturesquely situated, high above the hillsides, and is well sheltered from the cold winds on the north. It has an elevation of 1,070 feet, and possesses a very mild and salubrious climate, essentially the same as that of Cannes, with the exception that it is less stimulating than a resort directly upon the seashore. It is "a town of charming view, delicious water, and the best of air."

The temperature is a little lower in winter than that at Cannes, on account of the elevation; the mean temperature of the year being 60.2° and for the winter 46.4°, while that at Cannes is 60° and 47.75° F. respectively. "Grasse," say Weber and Foster (Albutt's "System of Medicine," 1896), "forms a useful intermediate station during April and May for patients who find the heat in those months already too oppressive at Cannes."

For the climatic detail one is referred to the articles upon Cannes and Nice. In brief, Grasse affords a favorable winter resort for invalids unable to remain near the sea. Grasse possesses a luxuriant vegetation and is celebrated for the cultivation of flowers and the manufacture of perfume, which is the most extensive in France, if not in the world. The air is heavy with the scent of flowers, which with some invalids is said to produce an exaggerated form of hay fever. Great fields of orange blossoms, heliotrope, hyacinth, roses, violets, jonquils, geranium, and other flowers are cultivated about Cannes and Grasse; 60,000 acres being devoted to this industry, yielding annually 2,200,000 pounds of roses and 4,000,000 pounds of orange flowers.

At the foot of the village are great plains of olive trees. The views are very beautiful and extensive, and the excursions round about are many and attractive. The town itself is not particularly attractive, but this is compensated for by its picturesque situation and beautiful views.

The water supply and drainage are good. The accommodations are good but apparently limited.

The climate is said to be beneficial to sufferers from asthma, gout, nervous affections, insomnia, neuralgia, and rheumatism. EDWARD O. OTIS.

Gratiolet, Louis Pierre.—Was born on July 6, 1815, at Sainte-Foy-Grande, France, where his father practised medicine. In 1825 his father moved the family to Bordeaux, where the younger Gratiolet began his studies. Later he went to Paris and became an interne at Salpêtrière, at that time called the Hôpital de Pitié. While there he also studied comparative anatomy with de Blaineville, the noted French zoologist, at the Museum. In 1842, Blainville made him his assistant in his laboratory of natural sciences, and in 1844 he became substitute professor to de Blaineville in the Chair of Natural Sciences. In 1845 he obtained his medical degree in order to finish the course in medicine, but with no idea of practising as his desire was to become a natural scientist and anatomist. At the death of de Blaineville in 1850 Gratiolet lost his position as substitute professor and again became an assistant scientist in the laboratory. In 1862, however, he was made substitute professor to the Chair of Zoology in the Faculty of Sciences, and in November of the same year became full Professor. He died February 16, 1865.

Gratiolet's laws are (1) Synostosis of the cranial bones occurs earlier in the inferior than in the superior races; (2) Ossification in the bones of the skull proceeds from behind forward in the higher races of man, from before backward in the lower races; these laws are not absolute. The term Gratiolet's radiation is given to the optic radiation described by him. Among his numerous scientific writings are the following: Mémoire sur les plis cérébraux de l'homme, 1854; Recherches sur le système vasculaire de la sangsue médicinale et de l'aulastome vorace, 1862; Sur les rapports entre les singes anthropomorphes et l'homme, 1865. Other important works, the dates of which are not known, are l'Anatomie comparée du cerveau de l'homme et des primates; Mémoire sur la microcéphalie et sur les caractères du groupe humaine. E. L. J.

Gravel.—See *Kidney, Surgical Affections of.*

Graves, Robert James.—The descendant of a family distinguished in many branches of science was born in 1797 in Dublin where he received his medical education. Later he studied on the Continent, returning to Dublin in 1821 to establish a practice. was one of the founders of a private medical school called the Park Street School, which later became a hospital. He was attending Physician to the Meath Hospital. In 1827 he was elected professor of the Institutes of Medicine in the King's and Queen's College of Physicians, Dublin. He died in Dublin on March 20, 1853.

Robert Graves was one of Ireland's most famous medical teachers and clinicians. He was one of the first to advocate and successfully carry out the idea of sufficiently feeding typhoid fever patients, as opposed to the "absolute diet" treatment then in vogue. He is credited with having expressed the wish for the epitaph on his tombstone, "He fed fevers." Graves' name has passed into history linked to exophthalmic goiter. The following are among his most important writings: A Lecture on the Functions of the Lymphatic System, 1828; Sketch on the Origin and Progress of Asiatic Cholera, 1841. A System of Clinical Medicine, 1848; Clinical Lectures on the Practice of Medicine, 1843, and published in the *Dublin Journal of Medical and Chemical Sciences;* Studies in Physiology and Medicine, 1853. E. L. J.

Great Bear Spring.—Oswego County, New York.

ACCESS.—Via the Oswego Branch of the New York Central and Hudson River Railroad, and the Delaware Lackawanna and Western Railroad to Fulton. The springs are situated five miles south of Fulton, and can be reached from this point by means of the Syracuse Lake Shore and Northern Electric Railway, which passes through the property. They can also be reached from Syracuse by means of this same electric road.

The springs are situated upon an uninhabited and reforested tract of nearly five hundred acres which comprises the entire watershed. The water of these springs is used exclusively for bottling, there being no sanatoria near them. The spring has been known for many years, having been used by the aborigines.

The Great Bear Spring Company maintains a laboratory for the scientific supervision of its operations.

There are no less than eleven springs, equally good, and with a combined flow of above one-half million gallons daily. The volume of water is unvarying, and it gushes forth at a temperature of about 50° F. throughout the year. That the flow of the springs is not affected by extreme drouth proves their deep source. The water is but feebly mineralized, but it is remarkably pure, and its freedom from organic matter gives it excellent qualities for the table. Its very small cost is an additional advantage.

The following analysis of water from Spring Phoenix was made in the Lederle Laboratories, New York, in 1912:

	Parts in one million.
CHEMICAL EXAMINATIONS:	
Iron	.350
Chlorine in chlorides	2.470
Nitrogen in nitrites	None.
Nitrogen in nitrates	1.500
Free ammonia	.006
Albuminoid ammonia	.010
Hardness equiv. to (before boiling)	103.700
Carbonate of lime (after boiling)	88.880
Organic and volatile (loss on ignition)	12.000
Mineral matter (non-volatile)	143.000
Total solids (by evaporation)	155.000
Oxygen consumed	1.450
PHYSICAL EXAMINATIONS:	
Appearance	Clear.
Sediment	None.
Color	None.
Odor (heated to 100° F.)	None.

EMMA E. WALKER

Green Sulphur Springs.—Summers County, West Virginia.

POST-OFFICE.—Green Sulphur Springs.

The following analysis of this water has been made by Booth, Garrett, and Blair, analytical and engineering chemists of Philadelphia.

	Grains per U. S. Gallon
Silica	0.711
Sulphuric acid radicle	9.233
Bicarbonic acid radicle	15.259
Carbonic acid radicle	0.583
Nitric acid radicle	0.000
Nitrous acid radicle	0.000
Phosphoric acid radicle	Trace
Boric acid radicle	0.000
Arsenic acid radicle	0.000
Chlorine	8.026
Bromine	0.000
Iodine	0.012
Iron	0.000
Aluminum	0.015
Calcium	2.671
Magnesium	0.571
Potassium	0.076
Sodium	11.339
Lithium	0.015
Ammonium	0.009
Oxygen to form Al	0.013
	48 533

Green Sulphur Water belongs to the class of sulphated alkaline-saline, sulphurated waters. These waters have been found to be valuable in the treatment of catarrhal conditions of the stomach, intestines, biliary passage, and urinary tract. In large quantities they act as purgatives, in smaller quantities as diuretics. Excellent results have followed their use in acid dyspepsia, rheumatism, gout and diabetes. Green Sulphur Water is recommended also for the treatment of many skin disorders, and in catarrhal conditions of the pharynx, larynx, and bronchi. The water has a distinct tonic effect. The source is an artesian well sixty-five feet deep. The well was bored in 1819. EMMA E. WALKER.

Greenbrier White Sulphur Springs.—See *White Sulphur Springs.*

Gregarinida.—Telosporida in which only the young trophozoites are intracellular, the fully grown forms being extracellular. These protozoans typically occur in invertebrate hosts. See *Protozoa.*

A. S. P.

Gregory, James.—The son of a physician, was born in Aberdeen in January, 1753. He studied medicine in Edinburgh and London, obtaining his degree in 1774. In 1790 he was appointed professor of clinical medicine in Edinburgh, succeeding Cullen, and was actively engaged in teaching up to the time of his death, April 2, 1821. Gregory was a skilful but cautious practitioner, being a firm advocate of the expectant treatment when no clear indications for medication appeared. A favorite prescription of his, even yet known as Gregory's powder, was the basis of the compound rhubarb powder of the British and United States Pharmacopœias. His medical writings were comparatively few, for he was unfortunately of a

FIG. 2831.—James Gregory.

somewhat irascible disposition and wasted much time in controversies with his colleagues, penning many pamphlets either attacking others or defending himself in sarcastic and often bitterly personal language. His two most important medical works were: "Dissertatio medica de morbis cœli mutatione medendis," Edinburgh, 1774 and 1776; and "Conspectus medicinæ theoreticæ in usum academicum," Ed. 1774, sixth edition, in two volumes, 1818. His son, James Crawford Gregory, also a physician, was born in Edinburgh in 1800 and died of typhus fever in 1832. Another son was a well-known chemist and professor of the University of Edinburgh.

T. L. S.

Griesinger, Wilhelm.—Born at Stuttgart, Germany, July 29, 1817. He received the degree of Doctor of Medicine from the University of Tübingen in or about the year 1838. After practising for a short time in his native city he was invited (1843) by his friend, Prof. Wunderlich, to be his assistant in the Medical Clinic at the University of Tübingen. He accepted the position, and a few years later (in 1847) he was elected Extraordinary Professor. In 1850 he accepted a call to take charge of a school of medicine in Cairo, Egypt, and to be at the same time the President of the Sanitary Commission and the physician-in-ordinary of the Khedive. He held these positions for only two years and then returned to Stuttgart, where he lived quietly until he was called (1854) to Tübingen to fill the positions (professor and director of the medical clinic) previously held by Wunderlich. In 1860 he accepted the corresponding positions in the University of Zürich; and in 1865 he removed to Berlin, where he devoted himself almost exclusively to mental and nervous diseases, his position as Director of the Psychiatric Department and the Department for Nervous Diseases in the Charité Hospital giving him ample opportunity for continuing his studies in these two branches of medical science. On October 26, 1868, he died from perforation of the vermiform appendix.

Griesinger's great merit rests upon the fact that he was the first to place psychical disorders upon a rational basis, and to discard wholly the spiritualistic

views which had, up to this time, played so prominent a part in the interpretation of those disorders. He also did much to improve the treatment of these affections, and his advocacy of the no-restraint system of psychiatry was of the most energetic kind.

Of the published writings of this celebrated psychiatrist and neurologist the best known and the most valuable is that entitled: Pathologie und Therapie der psychischen Krankheiten," Stuttgart, 1845 (latest edition, 1867). The following treatises also deserve to be mentioned. "Ueber Irrenanstalten and deren Weiterentwickelung in Deutschland;" "Die freie Behandlung;" "Weiteres über psychiatrische Kliniken;" "Ueber einige epileptoide Zustände;" "Ueber einen wenig bekannten psychopathischen Zustand;" and "Bemerkungen über die Diagnostik der Hirnkrankheiten." The first number of the newly established "Archiv für Psychiatrie und Nervenkrankheiten," which was edited by Griesinger, Roser and Wunderlich, was issued in 1868, before G.'s death.

Griesinger also deserves credit for having been the first German physician to recognize and to describe relapsing fever (febris recurrens) as an independent disease. (See Virchow's Handbuch der Speciellen Pathologie und Therapie, Bd. ii., Abth. 2. Erlangen, 1857 to 1864.) A. H. B.

Grindelia (U. S. P.).—California Gum-weed, *Rosin-weed.* The dried leaves and flowering tops of *Grindelia camporum* Greene, *G. cuneifolia* Nuttall or *G. squarrosa* (Pursh) Dunal. (fam. *Compositæ*). These are large and coarse perennial, resinous herbs, of the far western and southwestern United States.

The light-yellow or occasionally rose-tinted stems should not exceed 2 mm. in thickness. The alternate leaves are about 5 cm. (2 inches) or less long, varying from broadly spatulate or obovate to lanceolate, sessile or clasping, obtuse, more or less coarsely and sharply serrate, often spinosely toothed or even laciniate-pinnatifid, pale yellowish-green or yellow, very smooth, finely dotted, resinous, thick and brittle; heads many-flowered, the involucres of many series of imbricated scales with acute, spreading or recurved tips. The heads of *G. squarrosa* and *G. cuneifolia* are mostly longer than broad, contracted-campanulate or conical-urceolate; those of *G. camporum* are broader than long, depressed-urceolate. Ray-florets deep-yellow, ligulate, pistillate; disc-florets yellow, tubular, perfect; pappus of two or three mostly unequal awns, about as long as the disc-florets; odor balsamic, slightly narcotic; taste resinous and gummy, pungently aromatic, somewhat bitter. The quality is roughly indicated by the amount of resinous matter exuded upon the surface.

Resin is the principal constituent. There are also a little volatile oil, wax, gum and tannin, together with a bitter glucoside, in small amount. Its uses are external and systemic. The fluid extract, if painted upon a surface poisoned by rhus and similar agents, is one of our best remedies. It forms a dry coating which excludes the irritating atmosphere and prevents the spread of the poisonous fat, probably also absorbing it into the resinous film. It is of some similar use for treating burns and as an injection for urethritis and vesical catarrh. Its internal action, as a sedative expectorant, is not so readily explained. It is largely used, by way of the stomach, in chronic and subacute bronchitis, in asthma, and in whooping-cough. It is mostly given in the form of the official fluid extract, in doses of ♏ xv.–lx. (1.0–4.0). Henry H. Rusby.

Grippe, The.—See *Influenza.*

Grocer's Itch.—A form of itch caused by the mites *Glyciphagus prunorum* and *G. domesticus* which live in flour, sugar, etc. See *Arachnida.* A. S. P.

Gross, Samuel David.—Born near Easton, Pa., July 8, 1805. He was graduated from the Jefferson Medical College in 1828, and began practice in Philadelphia. In 1833 he became Demonstrator of Anatomy in the Medical College of Ohio, at Cincinnati, and two years later he was given the Professorship of Pathological Anatomy in the Medical Department of the Cincinnati College. It was here that he delivered the first systematic course of lectures on morbid anatomy ever given in the United States; and soon afterward he issued his "Elements of Pathological Anatomy," the first methodical treatise on the subject ever published on this side of the Atlantic or in

Fig. 2832.—Samuel D. Gross.

the English language. For ten years he held the Chair of Surgery in the University of Louisville, and then, upon the retirement of Dr. Valentine Mott, he accepted the same chair in the Medical Department of the University of New York. At the end of one session, however, he resigned the latter position and returned to his Louisville chair. In 1856 he was elected Professor of Surgery in the Jefferson Medical College, Philadelphia, and he filled that chair until within two years of his death which occurred on May 6, 1884.

Dr. Gross contributed many works to medical literature, but by far the most important of these is his "System of Surgery." The first edition of this most elaborate treatise was published in 1859; the sixth and last, in two large volumes profusely illustrated, appeared in 1882. In 1872 the University of Oxford, England, conferred on Dr. Gross the honorary degree of D. C. L., and that of LL. D. was given him by the University of Cambridge. Among the fathers of American medicine Dr. Gross deserves to hold a very high rank. A. H. B.

Ground Itch.—A skin eruption caused by the presence of the hookworm, *Ankylostoma duodenale* in the hair follicles of the skin. See *Nematoda.* A. S. P.

Growth.—This article is divided for convenience into four sections: I. Definition of growth. II. Growth as a function of cells and tissues. III. Human growth statistically considered. IV. The laws of mammalian growth.

I. Definition of Growth.—Definitions of growth have been given from two principal points of view. According to one of these, growth is defined as increase of size or volume. From this point of view any increase of volume is growth no matter to what cause it may be due, and differentiation is regarded as an entirely distinct phenomenon which may or may not accompany growth.

From the other point of view the term growth implies in a general way an increase in the number or size, or in both, of the histological elements; and also, but more vaguely, implies that the elements advance, or at least remain stationary in the scale of organization. In other words, if the increase in volume be due to developmental processes, or if it be accompanied by progressive differentiation, it is growth. But if, on the other hand, increase of volume be due to the deposition of products of degeneration, as, for example, fat, it cannot properly be regarded as growth. This definition is not so definite as the first, which, therefore, should be preferred.

II. Growth as a Function of Cells and Tissues. —It is evident that the growth of an organism is the sum of the growths of its tissues, and the growth of the tissues depends on that of the cells; hence growth ultimately rests upon, first, the increase in size of single cells, and, second, the multiplication of cells. Owing to their peculiar mode of growth, the plants afford the best material for the study of the process in its simplest form. At the tip of each stem or rootlet there is a mass of cells in an embryonic condition, and during rapid growth these cells undergo frequent cell division. There is at the extreme tip a cell or a group of cells that always divide by a transverse partition into a distal and a proximal daughter cell or cells. The daughter cell at the tip, the distal one, remains in an embryonic condition and divides again in the same manner. In this way the proximal daughter cell becomes separated from the tip by the successive divisions of the apical cell or group of cells. If we follow one of the proximal cells through its life history, we shall see that it at first divides repeatedly, forming a group of small cells with dense protoplasm and thin cell walls. This is the period of most rapid multiplication. A little later the process of cell division become less frequent in this group, and the cells become larger and exhibit large vacuoles containing a clear watery fluid. This is the period of greatest growth. Finally, the cells cease both to multiply and to increase in size; and the cell walls become thickened and assume the character of the tissue to which these cells belong. This is the period of histogenesis.

In the development of the plant cell, then, may be recognized three stages: (1) Multiplication, (2) growth, and (3) histogenesis. These three stages are represented by three zones in root or stem. The zone of multiplication surrounds the tip and extends but a short distance from it. Here growth takes place but slowly, so that between one act of division and the next a cell may double in size. But the most rapid growth is in the next zone, where a cell may increase to several times its original size without undergoing division. Sachs studied the daily rate of growth of the root of a bean (Phaseolus). A disc 1 mm. long was carefully marked off just behind the tip and was then measured daily. The rate of growth was found to increase from a little over 1 mm. on the first day to a maximum of about 14 mm. on the seventh day. After that the rate decreased rapidly to about 2 mm. on the tenth day.

From an analysis made by Kraus upon hothouse plants of *Heterocentron roseum* it was found that the percentage of water in the tissues increases from 73 per cent. at the tip of the stem to 88 per cent. at the first internode, and reaches a maximum of 93 per cent. in the second internode. Farther along the stem there is a slight decrease, the amount being 92.7 per cent. in the fifth internode. In plants, then, it appears that the period of most rapid growth is also the period of most rapid absorption of water by the cells.

In animals there is, as a rule, no area of embryonic cells to furnish material for growth for an indefinite period. On the contrary, the extent of growth for each species is more or less strictly limited by conditions of which we know very little. In the period of cleavage of the egg and anatomical differentiation (see article *Differentiation*) the whole embryo is in the condition found at the tip of the stem of a plant. The cells are all small, rich in protoplasm, and undergo division frequently, while there is little or no growth of the embryo as a whole. Then comes the period of most rapid enlargement accompanied by an increase in the amount of water, and this is followed by the period of histological differentiation. The relative rate of growth per unit of body weight decreases gradually until the animal reaches the limit of its species.

This was brought out by Davenport (1899) in his researches upon the embryos of frogs, the results of which are given in the following table:

Growth of Frog Embryos.

Days after hatching.	Average weight in milligrams.	Weight of dry substance in milligrams.	Weight of water in milligrams.	Per cent. of water.	Average increase daily in per cent. of body weight.
1.....	1.83	0 80	1.03	56	.....
2.....	2.00	0.83	1.17	59	9.3
5.....	3.43	0.80	2.63	77	23.9
7.....	5.05	0.54	4.51	89	23.8
9.....	10.40	0.72	9.68	93	54.0
14.....	23.52	1.16	22.36	96	25.2
41.....	101.0	9.9	91.1	90	12.2
84.....	1,989.9	247.9	1,742.0	88	.....

The frog embryo takes no food for several days after hatching, so that there is a loss of dry substance until about the eighth day; and yet it is between the seventh and ninth day that there is the greatest daily increment per unit of body weight. As the precentage of dry substance increases the rate of growth becomes less. The time of most rapid growth is the time when the cells absorb water most rapidly.

Similar results were obtained by Fehling (1877) from the measurement and analysis of twenty-one fresh human embryos, as shown in the following table:

Growth of Human Embryos.

Number.	Length centimeters.	Sex.	Age.	Weight.		Per cent. of water.
				Fresh grams.	Dry grams.	
1	2.5	F.	6th week	0.975	0.24	97.54
2	15.0	M.	4th month.....	36.5	3.0	91.79
3	13.5	M.	4th month.....	56.5	5.1	90.97
4	18.5	M.	5th month, 1st half.	95.5	8.9	90.7
5	18.5	M.	5th month, 1st half.	104.7	8.2	93.2
6	19.0	F.	5th month, 2d half.	156.8	14.6	90.7
7	21.5	M.	5th month, 2d half.	244.0	22.0	90.96
8	22.5	M.	5th month, 2d half.	235.0	24.0	89.81
9	23.0	F.	5th month, 2d half.	264.0	29.5	88.9
10	24.0	F.	5th month, 2d half.	299.0	32.8	89.3
11	26.0	M.	6th month.....	361.8	39.1	89.2
12	30.0	F.	6th month.....	575.0	79.5	86.4
13	33.5	M.	6th month.....	771.0	125.0	83.77
14	34.5	F.	7th month.....	910.0	159.0	82.6
15	34.0	M.	7th month.....	832.9	138.2	83.5
16	36.0	F.	7th month.....	836.0	136.5	83.9
17	35.0	M.	7th month.....	1,117.0	170.71	84.8
18	38.0	M.	8th month.....	928.0	159.5	82.9
19	53.5	M.	Term.....	3,284.0	855.52	74.1*
20	44.0	M.	9th month.....	1,760.6	456.1	74.7†
21	45.0	M.	9th month.....	1,495.7	391.2	73.9‡

* Still-birth.
† Died in uterus.
‡ Premature births; atrophic; died thirteen days later.

It will be noticed that the youngest embryo, in the sixth week, contains the largest proportion of water, 97.54 per cent. From that the proportion decreases to about 74 per cent. at the time of birth.

For comparison with the growth of the human embryo Fehling studied the growth of embryo rabbits. For this purpose he reckoned the age of the fetus in priods of three days, each period being supposed to correspond to a month of human gestation. Two embryos, the largest and the smallest, were chosen from each litter for analysis. Some of his results are given in the following table:

Weight of Rabbit Embryos.

Number.	Weight of mother.	Period.	Weight of Fetus in Grams.		Per cent. of water.
			Fresh.	Dry.	
1	1,850	5	0.619	0 052	91.5
2	1,850	5	0.663	0.057	91.4
3	1,500–1,600	7	10.631	1.5	85.9
4	1,500–1,600	7	12.83	1.7	86.7
5	.....	8	23.6	3.5	86.3
6	.....	8	24.6	4.0	83.8
7	.....	8	15.95	2.25	85.9
8	.....	8	12.3	2.0	82.2
9	1,806	8	18.61	2.94	84.2
10	1,806	8	18.68	2.32	87.6
11	3,240	9	62.35	11.35	81.8
12	3,240	9	45.78	7.6	85.6
13	2,854	9	41.98	8.0	81.0
14	2,854	9	50.33	9.33	81.5
15	1,800	9	29.25	4.9	83.2
16	1,800	9	28.56	5.83	79.6
17	About 1,800	10	34.29	7.22	79.0
18	About 1,800	10	33.05	6.7	79.7
19	.....	New-born	38.4	8.4	78.4
20	.....	New-born	38.3	8.8	77.1
21	.....	14 days.	179.5	43.8	75.6
22	.....	14 days.	224.0	75.4	65.1

The weight of the mother has great influence on the weight of the fetus, and is given for that reason in this table. This factor is of less importance in human statistics, where the range of variation is comparatively much restricted.

The table shows a gradual decrease in the percentage of water in the tissues of the fetus, and this is associated, as in man, with a gradual decrease in the relative rate of growth as shown in the following table:

Growth of Rabbit Embryos.

Period.	Weight of beginning of period. Grams. a	Absolute growth during period. Grams. b	Relative growth per period. $\frac{b}{a}$
5	0.619	5.557	8.97
6	6.176	5.558	0.89
7	11.734	6.916	0.59
8	18.65	10.258	0.55
9	28.908	4.762	0.16
10	33.67	4.68	0.13
Term	38.35		

The figures for the sixth period in this table are somewhat doubtful, for there is nothing to show that they were obtained by actual observation.

All these results tend to show that in both animals and plants the most rapid increase in weight in proportion to the weight of the body takes place at the time when the tissues are at their least density. As the solid constituents of cells increase the relative rate of growth decreases.

The relation between growth and the absorption of water has again been demonstrated by studies made by Glaser (1914) on young embryos of the frog and Amblystoma. In these the most rapidly growing part is the dorsal region including the nervous system, and in this the brain is growing faster than the rest; while the ventral part of the embryo, consisting largely of inert endodermal cells laden with yolk, lags behind. Glaser separated these parts and by drying and weighing obtained the following average results:

Amblystoma 31 whole larvæ	58.6 per cent. water
Rana pipiens 55 yolk sacs	54.2 per cent. water
Rana pipiens 55 nervous systems	80.1 per cent. water
Amblystoma 136 nervous systems	79.7 per cent. water
Amblystoma 125 larval cords	79.0 per cent. water
Amblystoma 125 larval brains	82.8 per cent. water

Little is known of the effects of external conditions upon the rate of growth of animals, but upon the growth of plants external conditions have been shown to have a very marked effect. For full discussion of this subject the reader should consult Davenport's very excellent summary ("Experimental Morphology, vol. ii., 1899).

III. Growth of Man.—We divide the subject as follows: 1 Prenatal growth; 2, weight of the newborn child; 3, growth of infants, 0 to 5 years; 5, growth of children; 6, size of adults.

1. *Prenatal Growth.*—From observations on forty-three specimens, together with the data previously collected by others, Jackson (1909) has constructed the following table showing the prenatal growth of the human body by months:

Lunar month.	Weight at beginning of month (a).	Weight at end of month (b).	Relative monthly growth $\frac{b-a}{a}$.
I	0 000004g.	0.04g.	9999.0
II	0.04	3.0	74.0
III	3.0	36.0	11.0
IV	36.0	120.0	2.33
V	120.0	330.0	1.75
VI	330.0	600.0	0.82
VII	600.0	1000.0	0.67
VIII	1000.0	1500.0	0.50
IX	1500.0	2200.0	0.47
X	2200.0	3200.0	0.45

It will be seen that during the first month the rate of growth relative to the size of the embryo is enormous. From this time the relative rate decreases at first very rapidly and then more and more slowly. The absolute growth on the other hand increases, at first slowly and then more rapidly. So that the gain in weight during the ninth month alone exceeds all the grains of the first six months put together. Jackson finds that the absolute growth after the first month may be represented by a fairly regular curve that corresponds roughly to the formula.

$$\text{Weight (g)} = \frac{\text{age (days)}^4}{37}$$

2. *Weight of the New-born Child.*—It is subject to very considerable variations. For middle Europe the average may be held to be about 3,340 grams for boys, 3,190 grams for girls, the latter being somewhat lighter. The variations are very great, ranging from 1,000 to 5,000 grams. For instance, the following table is given by Pfannkuch, who unfortunately jumbles the two sexes together:

Kilograms.	Obs.	Kilograms.	Obs.
1.50 to 2.0	23	3.00 to 3.25	150
2.00 to 2.25	36	3.25 to 3.50	115
2.25 to 2.50	52	3.50 to 3.75	79
2.50 to 2.75	90	3.75 to 4.00	46
2.75 to 3.00	110	4.00 to 4.50	13

It will be noticed that the maximum number of cases (150) falls between 3.00 and 3.25 kilograms, and that the further the weight is removed on either side, above or below, from this mean, the fewer are the cases. The tables by other authors show the same general results, with usually slight differences in the quantitative values.

The factors which determine the weight at birth are very obscure. It is, of course, safe to say, vaguely, that it depends on the nutrition of the fetus; it is probable that individual differences in the rate of growth exist before as well as after birth, and it is probable that the length of gestation is the most influential single factor, to judge from Minot's experiments on the growth of mammals.

It has been demonstrated that the variations in the weight of the child depend upon various maternal circumstances.

First. It is correlated with the age of the mother, as is shown in the following table, giving the weight of the children in grams according to three observers:

Age of the mother.	Ingerslev.	Fassbender.	Petersson
15 to 19 years	3,241	3,271	3,451
20 to 24 years	3,299	3,240	3,485
25 to 29 years	3,342	3,333	3,591
30 to 34 years	3,375	3,367	4,062
35 to 39 years	3,428	3,292	3,591
40 to 44 years	3,326		3,676

From such tables we learn that very young mothers have the smallest children, and those of about thirty-five years the heaviest. It is much to be regretted that the tables do not show the correlation by single years, and also the number of observations.

Second. The weight of the child increases with the weight (Gassner) and stature (Frankenhäuser) of the mother. Gassner states that the weight of the child is to that of the mother as 1 to 19.13, or 5.23 per cent. of the maternal weight. Frankenhäuser states that if the height of the mother is less than 4 feet 6 inches, the child weighs 6 pounds 15 ounces; if it is 4 feet 6 inches to 4 feet 11 inches, the child weighs 6 pounds 25 ounces; if it is more than 4 feet 11 inches, the child weighs 7 pounds 3 ounces.

Third. The weight of the child increases according to the number of previous pregnancies, as indicated by the following table:

Number of pregnancies.	Hecker. Gm.	Ingerslev. Gm.
One	3,201	3,254
Two	3,330	3,391
Three	3,353	3,400
Four	3,360	3,424
Five	3,412	3,500
Six	3,353	....

Here again we encounter faulty statistics, for it is not shown that we have any other effect than that of age, for the conclusion claimed cannot be established until it is proved that primiparæ have smaller children than multiparæ *of the same age.*

Fourth. Negri has maintained (*Annali di ostetricia,* 1885) that the compilation of 333 observations shows that the children of women whose menstruation is early are larger than the children of those whose first menstruation is late.

Fifth and sixth, the influence of race and climate, which have not yet been subjected to any proper exact study.

In conclusion, it seems probable that all these influences produce their effect principally by prolonging or abbreviating the period of gestation. In other words, the variations in the weight of children at birth are to be referred immediately to two principal causes: (1) Differences in the age at birth; (2) individual differences of the rate of growth in utero.

3. *Growth of Infants.—(a) Alteration in weight during the first week.* There is an interruption of the normal rate of growth during a few days after birth, both in man and other mammals (Section IV.). It lasts for a variable period, and is variable in degree. In most cases, with the human species, it is so great as to cause an actual loss of weight, but frequenty it shows itself only as retarded growth. During the first month the average daily increase is about thirty-five grams (Fleischmann), but during the first two or three days, or sometimes more, the rate of increase is very much less, often even negative. Gregory, for instance, gives the following data:

Day	1	2	3	4	5	6
Number observed	33	33	33	33	33	33
Weight change, grams	−139	−64	+33	+50	+50	+36

The retardation of the growth is prolonged by defective nutrition, of which the cause may lie in either the mother or the child, and by illness of the child. A healthy baby ought to get back to its initial weight by the sixth or seventh day, and failure to reach the initial weight by the ninth day may be taken as an indication of illness.

The cause of the postnatal retardation is not fully elucidated. That it is not due to the mother's condition is shown by two considerations: (1) The retardation occurs also in chicks at hatching, although they are not dependent on the parent for nutrition; (2) Ingerslev put sixteen children, just born, to wet-nurses, who had borne four to five days previously and gave abundant milk, nevertheless the children all lost weight. It seems probable that the loss is due to the establishment of respiration, and to the increased expenditure (metabolism) of the body to maintain the normal temperature. During gestation and incubation the parent supplies caloric to its young, but after birth (or hatching) the young is self-dependent, and rapidly wastes its tissues to keep up its body warmth.

(*b*) *For the growth from the first to the fifty-second week* we must depend chiefly on—(1) the careful compilation given by Meek and quoted by Vierordt, in which, however, the sex, nutrition, race, and social condition of the children are not considered, all factors which have a very great influence on the weight; (2) the observations of Albrecht (*Centralzeitung f. Kinderheilkunde,* 1879, No. 7), who followed the growth of eighty children at Berne. From Meek the following data are taken:

Week.	No. of observations.	Weight, gm.	Week.	No. of observations	Weight, gm.
First	22	3,228	Twenty-eighth	21	7,187
Second	25	3,367	Thirty-first	19	7,524
Third	31	3,412	Thirty-fourth	19	7,842
Fourth	31	3,532	Thirty-seventh	18	8,126
Seventh	33	4,103	Fortieth	17	8,344
Tenth	34	4,600	Forty-third	17	8,533
Thirteenth	36	5,022	Forty-sixth	17	8,760
Sixteenth	34	5,529	Forty-ninth	15	8,995
Nineteenth	32	5,864	Fiftieth	15	9,102
Twenty-second	26	6,497	Fifty-first	14	9,198
Twenty-fifth	23	6,925	Fifty-second	8	(10,172)

Albrecht states that in his experiments, taking the weight of the child at 3,300 grams at birth, the following is the average daily increase for each month in grams:

Month	1	2	3	4	5	6	7	8	9	10	11	12
Grams	30	29	29	24	20	18	14	11	11	9	8	7

The corresponding figures by Bouchaud are:

Month	1	2	3	4	5	6	7	8	9	10	11	12
Grams	25	23	22	20	18	17	15	13	12	10	8	8

By Fleischmann:

Month	1	2	3	4	5	6	7	8	9	10	11	12
Grams	35	32	28	22	18	14	12	10	10	9	8	6

The individual variations are very great, and the growth of any indivdual goes by fits and starts. A considerable delay in growth is not important, even if lasting for several, say three or four, weeks, as it is

counterbalanced by a subsequent excessively rapid growth.

5. *Growth of Children.*—Concerning school children we possess a good many valuable data. The best statistics by far are those of Bowditch. The average weights obtained by him are given in the accompanying table in kilograms; the clothes make up about eight per cent. of the weights given. The average standing heights, without shoes, is given for both sexes in the same table. These data refer to nearly twenty-five thousand measurements on the school children of Boston, Mass.

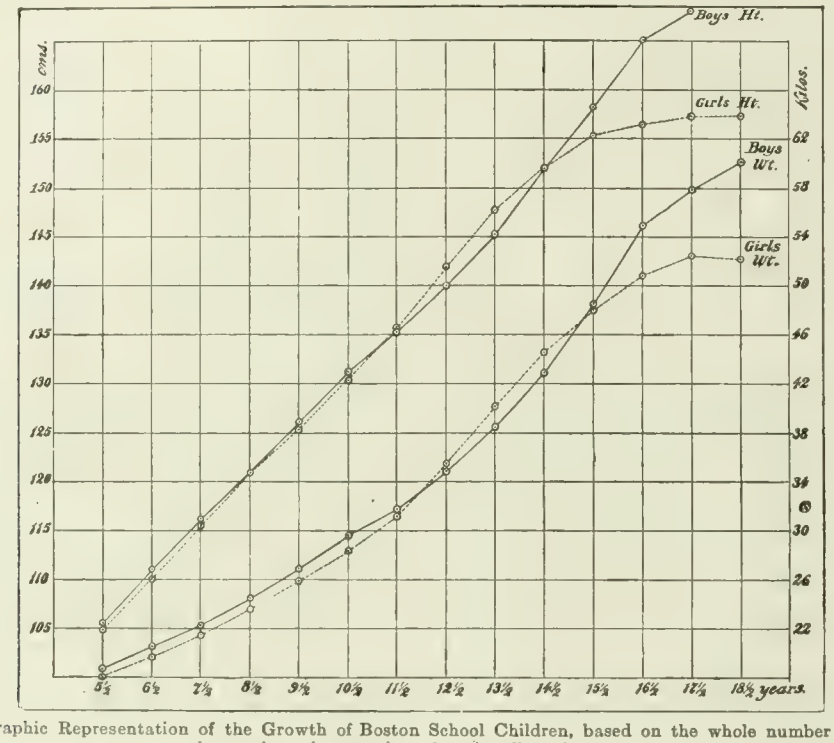

FIG. 2833.—Graphic Representation of the Growth of Boston School Children, based on the whole number of Bowditch's observations, irrespective of nationality of parents.

GROWTH OF BOSTON SCHOOL CHILDREN.

Age.	Boys.			Girls.		
	Height in cm.	No. of observations	Weight, kgm.	Height in cm.	No. of observations	Weight, kgm.
5 to 6 years	105.6	848	18.64	104.9	605	17.99
6 to 7 years	111.1	1,258	20.49	110.1	987	19.63
7 to 8 years	116.2	1,419	22.26	115.6	1,199	21.53*
8 to 9 years	121.3	1,481	24.46	120.9	1,299	23.61*
9 to 10 years	126.2	1,437	26.87	125.4	1,149	25.91
10 to 11 years	131.3	1,363	29.62	130.4	1,089	28.29
11 to 12 years	135.4	1,293	31.84	135.7	936	31.23
12 to 13 years	140.0	1,253	34.89	141.9	935	35.53
13 to 14 years	145.3	1,160	38.49	147.7	830	40.21
14 to 15 years	152.1	908	42.95	152.3	675	44.65
15 to 16 years	158.2	636	48.56	155.2	459	48.12
16 to 17 years	165.1	359	54.90	156.4	353	50.81
17 to 18 years	168.0	192	57.84	157.2	233	52.41
18 to 19 years	169.3	84	60.13	157.3	155	52.24

The results are more easily followed in the graphic representation, Fig. 2833, the ordinates represent the heights or weights, the abscissæ, the ages. We can distinguish three periods: (1) The steady growth of childhood, up to ten and one-half or eleven years in girls, to twelve or twelve and one-half in boys; (2) the period of prepubertal acceleration, when the growth is much more rapid, lasting in girls from eleven to fourteen or fifteen, in boys from twelve and one-half to sixteen and one-half; (3) the postpubertal decline. In girls the prepubertal acceleration begins earlier and is more marked than in boys; hence, though during childhood girls are smaller than boys, yet from twelve to fifteen they outstrip them, and are both taller and heavier than boys of the same age. Puberty ensues later in boys than in girls. (See article, *Age.*) The postpubertal falling off in growth is more rapid in girls than in boys; accordingly, after the fifteenth year boys gain fast over the girls. That the acceleration is really prepubertal is shown by the fact that the age of the first catamenia averages in Boston about fourteen and one-half years, so far as determined by the present imperfect statistics. Pagliani has proved the same relation in Italy. Most conclusive is the record of the growth of individuals, which demonstrates that the first menstruation is preceded by rapid, and followed by slower, growth.

Dr. Bowditch has shown, also, by his statistics that the children of American-born parents are, in the community of Boston, taller and heavier than children of foreign-born parents, a superiority which depends probably chiefly on the greater average comfort in which such children live and grow up, and partly upon differences of race and stock. The children of the well-to-do classes are taller and heavier than those of poorer classes. American (Boston) boys are taller for their age than English boys, concerning whom we have statistics, and are also heavier in proportion to their height; the comparison holds between the laboring classes and the upper classes both, as well as between boys taken without distinction. Incidentally it may be said that the popular conception of a "Yankee," as tall and slim, has no foundation in life

*In Bowditch's tables, as printed, incorrect numbers are given.

the Yankee, on the contrary, being stouter than the Englishman.

MacDonald (1899) gives some interesting results of the study of school children in Washington, D. C., containing data from 16,473 white children and 5,457 colored children. He gives measurements of heights, sitting heights, weights, and circumference of head, classified by age, parentage, and mental ability. As regards growth, these results in general confirm those obtained by Bowditch, except that American white boys appear to be inferior in weight to boys of foreign parentage. Mental ability appears to be correlated with circumference of head and with height and weight, except that dull boys of American non-laboring classes are on the average taller and heavier than the bright boys.

In general it may be said that growth is favored by healthful conditions; it is impaired by illness, probably, of any kind, but, of course, by some diseases much more than by others. It is favored by country more than by city life; by outdoor more than by sedentary occupations; by summer more than by winter; by vacation more than by attendance on school. A considerable body of statistical material on these and similar points is available, but unfortunately it is much scattered and has never been collated.

A summary of the chemical changes associated with the growth of warm-blooded animals is given by Aron (1913). In general it may be said that there is a decrease in water and an increase in the proportions of fat, protein, and ash. If the tissues free from fats are considered alone the decrease in proportion of water is much less, but is still perceptible. There is a marked increase in fat just before or after birth, which, doubtless, has an important physiological significance. Important changes occur in the consistency and chemical composition of the fat, which in young babies is nearly solid while in grown persons it is more fluid and oily. The melting point decreases from 47.2° C. in an eight and one-half months embryo to 27° C. in a person twenty-six years old. Parallel changes have been observed in a number of organs, but the blood shows much less change than the organs.

6. *Size of Adults.*—Measurements of recruits furnish a large mass of statistics concerning the size of adult men: the best worked out are the data in regard to the American army, as discussed by Gould and Baxter. The former had the material collected by the Sanitary Commission during the Rebellion; the records were hastily and inaccurately made by the single States, but the number of observations was so large that the errors may have corrected themselves to a considerable extent. Baxter, whose material was much more extensive and reliable, has not thought it worth while to tabulate the weights in proportion to age, but gives good tables of the stature.

Gould's Table of the Mean Weights of White Soldiers

Age.	No. of observations.	Weight, lb.	Age.	No. of observations.	Weight, lb.
16	216	121.03	36	184	149.29
17	456	128.02	37	167	148.81
18	1,100	133.93	38	153	147.22
19	1,150	137.05	39	123	146.38
20	1,357	141.38	40	98	150.01
21	1,446	143.06	41	61	146.30
22	1,351	143.60	42	102	146.97
23	1,108	144.31	43	73	145.62
24	1,059	146.31	44	83	152.79
25	745	146.84	45	67	147.06
26	599	147.05	46	37	146.97
27	551	146.93	47	19	145.05
28	512	147.21	48	35	146.82
29	386	145.51	49	10	145.19
30	395	147.62	50	21	138.06
31	242	147.65	51	12	144.25
32	298	146.00	52	10	139.49
33	225	148.53	53	11	151.15
34	225	148.29	54	8	159.60
35	339	145.57	Over 54	20	143.49

From this table the increase in weight is seen to continue up to about the thirty-fifth year, but the figures of the weights are irregular after the number of observations falls below 600. That the period of growth reaches to this age is more clearly shown by Baxter's table of the height at different ages.

Table of Ages and Corresponding Heights (Without Shoes) of 190,621 American Born White Men Found Fit for Military Service.

Age.	Number of observations.	Height. Inches.	Height. Meter.
Under 17 years	468	64.11	1.6284
17 years	937	65.67	1.6675
18 years	30,456	66.39	1.6863
19 years	14,994	67.07	1.7036
20 years	11,526	67.51	1.7148
21 years	14,146	67.78	1.7216
22 years	10,479	67.92	1.7252
23 years	8,907	68.01	1.7275
24 years	7,335	68.02	1.7277
25 years	7,940	68.05	1.7285
26 years	6,986	68.09	1.7295
27 years	6,351	68.11	1.7300
28 years	6,033	68.13	1.7305
29 years	4,447	68.17	1.7315
30 years	6,256	68.18	1.7318
31 years	5,562	68.20	1.7323
32 years	4,635	68.20	1.7323
33 years	3,939	68.29	1.7346
34 years	2,782	68.35	1.7361
35 years	4,966	68.47	1.7391
36 years	4,138	68.28	1.7343
37 years	4,172	68.26	1.7338
38 years	4,014	68.24	1.7333
39 years	3,402	68.23	1.7330
40 to 45 years	15,750	68.23	1.7330

These tables show that it is necessary to be extremely cautious in fixing upon any year to mark the adult age, for the cessation of growth is so gradual that its ending cannot be determined. In practice, it is convenient and sufficiently accurate to call twenty-five the adult year; for women it ought probably to be somewhat less. Bowditch (1890) gives the results of observations made on 1107 women in Massachusetts, most of them in schools and colleges, seventeen years old and upward. He finds the average height (without shoes) to be 158.76 centimeters, and the average sitting heights to be 53.24 per cent. of the total stature. Sargent (1889) gives the median weights of 1901 women aged 16 to 26 years as 52 kilograms, or 114.6 pounds (without clothes).

IV. The Laws of Mammalian Growth.—Extensive investigations of the laws of growth have been made by Minot (1908). He regards the absolute increments as less significant than the proportion of increase to the weight of the growing body. Accordingly he takes the rate of growth for any period as the ratio of the increments during that period to the weight of the animal at the beginning of the period. Minot's experiments were made chiefly on guinea-pigs, but include also rabbits and chickens. Fig. 2834 summarizes the most important general results of these experiments; the chart refers only to male guinea-pigs, it not being necessary to include the females or other animals.

The chart shows that the daily increase during the first three days in zero. This is due to the postnatal retardation, which is very marked in guinea-pigs, as it is also in man. The exact data are:

	Weight. grams.	Increase.
At birth	70.8	.....
One day	68.9	−1.9
Two days	70.0	1.1
Three days	73.4	3.4
Four days	77.3	3.9

The daily gain slowly increases till about the fourteenth day, and then slowly but steadily falls off. The observations are so few in number that there are many irregularities, which need not be heeded in this article.

As regards the guinea-pig, Fig. 2834 shows at once that as soon as the animal has recovered from the

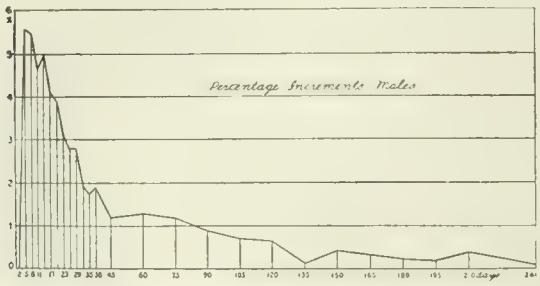

Fig. 2834.—Curve Showing the Daily Percentage Increments in Weight of Male Guinea-pigs. (Minot.)

postnatal retardation its relative rate of growth declines steadily. The observations of Fehling upon the embryos of man and rabbits show that this retardation in the relative rate of growth begins long before birth, and observations on plants make it probable that it has its beginning with the commencement of histological differentiation. The rate of growth of the human embryo during the first month, assuming the ovum to weigh 0.000004 gram, is estimated by Jackson (1909) to be between one million and fifty million per cent. From this it declines at first very rapidly and then more slowly to less than twenty per cent. during the ninth month (Minot, 1908, Fig. 2835).

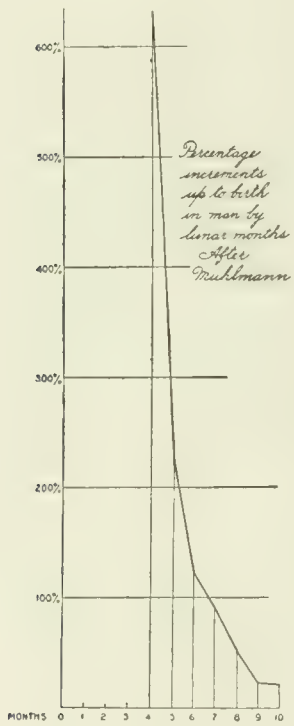

Fig. 2835.—Curve of Relative Growth in Man During the Last Seven Months of Gestation. (Minot.)

The constant loss in the rate, which appears to be the fundamental law of growth, at least in mammals and probably in all metazoa, may be shown in another manner very strikingly. If we calculate at what age after birth the animal will have added ten per cent. to its original weight, and then the age at which it will have again added ten per cent. to its weight at the end of the first period, and so on, we obtain the accompanying curve (Fig. 2836).

To make the first addition of ten per cent. requires long, 4.1 days, owing to the postnatal retardation; the second addition takes only 1.5 days; the succeeding additions occupy increasing periods, overlooking slight irregularities. In other words, the older the animal the longer it requires to add ten per cent. to its weight. In this chart, also, we see the decline progressing during the so-called period of development.

The same law of decline holds true for rabbits and chickens, and also for man. In man there is a very noteworthy modification, produced by the very marked prepubertal acceleration of growth, during which the decline is interrupted, as shown by Minot's calculations from Bowditch's tables; but compared with the whole course of decline the interruption is but slight, and is counterbalanced by an over rapid postpubertal decline. No essential importance is to be assigned to this phenomenon, since it is well known to embryologists that during development there are often displacements in time and in the growth of individuals. Minot observes that an accidental quickening or slowing of growth is followed by a reverse period, in the first case of slowing, in the second of quickening. There appears, therefore, no objection to the conclusion that in man also the period of apparent development is a period of real decline.

This leads us to the corollary that the stoppage of growth is not due to the reaching of maturity, but is merely the final term of a series of losses. It has been

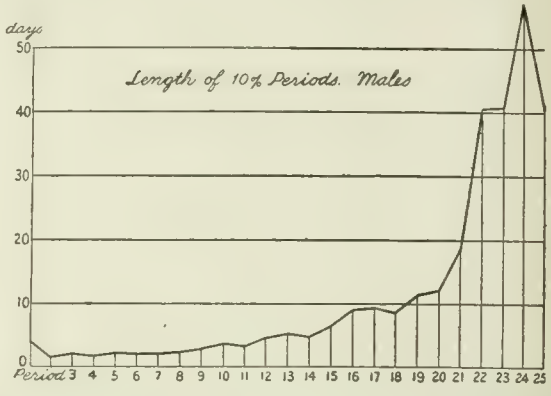

Fig. 2836.—Curve Showing the Length of Time Required to make each Successive Increase of 10 Per Cent. in Weight by Male Guinea-pigs. (Minot.)

asserted by Herbert Spencer, Carpenter, and others, that there is an inherent opposition between growth and reproduction, because the assimilative processes cannot perform enough to supply material for the growth of mother and offspring both. These authors and their followers see in the commencement of reproduction the beginning of a tax upon the organism which stops its growth; but as Minot has pointed out, the cause is mistaken for the effect, and probably the loss of vital force is the stimulus causing reproduction. Certainly the decline, which goes on from birth, cannot be caused by a phenomenon which begins only when the decline is nearly completed. Direct observations show that Spencer's view is erroneous, for growing guinea-pigs will bear one-third of their own weight of young while growing, and still reach as full an adult size as those producing no young (Hensen). Minot's experiments suggest that they become even larger. We thus learn that the fundamental conception on which Spencer's theory rests is imaginary—the conception being, that the assimilative power is approximately equal only to the needs of the growing animal. In reality there is a large excess of assimilation possible within normal limits.

As a result of her experiments on the spotted salamander, Miss Springer (1909) agrees with Minot that the initial weight is the chief factor in determining the rate of growth; and she makes the interesting observation that when the weight has been reduced, as by previous starvation or by cutting off the tail (fifteen per cent. loss), although the effects are not strictly comparable, the result is the same—an increase in rate of growth. She finds, however, that within limits the rate of growth is directly proportional to the amounts of food taken, and she

attributes the decrease of rate with increase of size to the greater need of the larger animal for food to maintain its equilibrium.

The next point to be noticed is that animals tend, as they grow, to approximate to the special size of the species. This shows itself, according to Minot, by the fact that the range of variation is less for adults than for the young. The following table shows this, averages being based on 4,200 observations in all:

Male Guinea-pigs.

Age.	Variation above, per cent.	Variation below, per cent.
0 to 0 day	19.51	19.49
1 to 15 days	18.95	18.99
16 to 30 days	17.13	16.87
31 to 65 days	15.68	16.31
70 to 140 days	12.12	13.31
145 to 215 days	7.52	7.48
8 to 12 months	10.66	9.72
13 to 17 months	10.38	11.41
18 to 24 months	12.10	10.82

The variation of adults is barely over half that at birth in range. Remarkable is the low variation from 145 to 215 days, and from 8 to 12 months. The higher values for older periods is perhaps due to variations in obesity, which we know from common observation increases in the human species with age. Jackson (1913), using white rats, obtains a different relation between variability and growth. His results are based on fewer observations, 570; but the variability is more exactly expressed by the coefficient of variation, $C = \frac{\sigma}{A}\ 100$ (see article *Variation*). He finds the variability of body weight to be lowest at birth, $C = 12$, and highest at three weeks, $C = 28$. At later periods the variability in weight ranges from $C = 19$ to $C = 21$.

The growth of an individual also indicates the existence of a tendency to attain the typical adult size; if the growth of the animal is retarded by illness, after recovery the growth is accelerated to make up. This has practical importance, for, unless the illness of a child is very prolonged, no permanent effect upon its size is to be anticipated.

The size of an animal or the limit of its growth depends upon, first, the rate, and second, the duration of its growth. This is well shown by comparing man with the rabbit and the guinea-pig, as to the average daily growth. A man acquires a weight of about 63,000 grams in twenty-five years; a rabbit, of the larger breeds, about 2,500 grams in one year, and a guinea-pig about 750 in the same period. For man add 280 days, for rabbits 30 days, for guinea-pigs 68 days, on account of the period of gestation.

Man	63,000 gm.	÷	9,139	+	280	= 6.69 gm. per diem.
Rabbit	2,500 gm.	÷	365	+	30	= 6.30 gm. per diem.
Guinea-pig	750 gm.	÷	365	+	68	= 1.73 gm. per diem.

Man grows about as fast as a rabbit, but becomes much bigger, because he grows longer; but the rabbit is bigger than the guinea-pig, because he grows much faster. This is matter of common observation; all that we gain from our calculation is a quantitative expression more suited for ready comparison.

Of course, the whole shaping of the organism depends upon variations in the growth rates of the single parts. With respect to variability Jackson (1913) classifies the individual organs in three groups: (1) head, brain, and eyeballs, with least variability, average coefficient 10 to 12; (2) the heart, lungs, hair, suprarenals, and kidneys, with moderate variability, coefficients 21 to 26; and (3) the thymus, spleen, gonads, and intestinal canal (with contents) are very variable with a coefficient above 29. The relation between the weight of various organs and the total weight of the body in white rats of various sizes has been investigated by Hatai (1913). He expressed the relation by the formula:

$$y = ax + b \log x + c,$$

where y = weight of organ, x = weight of body and a, b, c, are constants to be determined from the data. Curves drawn by this or a similar formula, may be classed in three groups: (1) for the growth of the brain, spinal cord and eyeballs, showing very rapid growth at an early period followed by very slow growth; (2) for most other viscera, an early rapid growth followed by a less rapid but steady gain, represented by an almost straight line; (3) for the ovaries and testes, irregular curves, showing three phases, the middle one being the period of most rapid growth. Sexual differences were observed in the growth of the suprarenals and the hypophysis, these organs attaining their maximum size much earlier in the female than in the male.

Robert Payne Bigelow.

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Gruber, Ignaz.—Born in Vienna, Austria, in 1803. During the early years of his professional life he was physician for cholera patients, first in the Litschak Hospital in Lemberg, and afterward in one of the Vienna hospitals. From 1833 to 1835 he busied himself with the writing and publication of a treatise on medical chemistry, which was received with much favor. After 1835 he devoted himself exclusively to otology. His chief contribution to this department of medicine was the discovery of the usefulness of the cone-shaped ear speculum (made in a single piece of metal, or other material, and non-expanding). This was a most valuable discovery, as the old type of speculum, with adjustable handles, easily caused the patient much discomfort or even pain, and necessitated, in all operative work, the employment of an assistant. He died September 28, 1872. A. H. B.

Gruber, Josef.—Born at Kosolup, in Bohemia, on August 4, 1827. He received the degree of Doctor of Medicine in 1855 from the University of Vienna. In 1863 he was appointed Dozent in Otiatrics, in the same institution, and in 1870 he became Extraordinary Professor of Otology. In 1873 he was made Director

of the newly established Otiatric Clinic. Then he was kept waiting for twenty years before the title and privileges of a full professor were finally (1893) bestowed upon him. In the meantime—that is, from 1864 onward—he held the official position of Aural Surgeon to the Königl. Kaiserl. Allgemeine Krankenhaus. Of his published writings the following deserve to receive special mention: "Anatomisch-physiologische Studien über das Trommelfell und die Gehörknöchelchen," Vienna, 1867; and "Lehrbuch der Ohrenheilkunde," Vienna, 1870 (2d edition, 1888). He was also one of the editors of, and a frequent contributor to, the *Monatschrift für Ohrenheilkunde, etc.* He died on March 31, 1900. A. H. B.

Guacamphol, guaiacol camphorate, occurs in white, needle-like crystals or powder, and is tasteless and odorless, and soluble in alcohol or chloroform but insoluble in water. It is said to pass unchanged through the stomach, and to split up in the intestines into guaiacol and camphoric acid; so it has been employed as an intestinal antiseptic, particularly in tuberculous diarrheas. It has also been recommended for combating the night sweats of pulmonary tuberculosis. The dose is 0.5–1 gm. (gr. viij.–xv.) in capsule at bedtime. W. A. Bastedo.
R. J. E. Scott.

Guadalajara.—See *Mexico.*

Guaiacol.—*Methyl-pyrocatechin.* $C_6H_4.OH.OCH_3$. Guaiacol constitutes from sixty to ninety per cent. of wood creosote, from which it is separated by fractional distillation, the boiling point of guaiacol being 206° to 207° C. "It is a colorless, crystalline solid, melting at 28.5° C. (83.3° F.), or a colorless refractive liquid, boiling at 205° C. (401° F.), having an agreeable aromatic odor. Specific gravity of liquid. 1.140 at 25° C. (77° F.), soluble in 53 parts of water at 25° C. (77° F.), and in alcohol and ether in all proportions; soluble in acetic acid and in 1 part of glycerin" (U.S.P.). Guaiacol may also be prepared synthetically from catechin, and by the dry distillation of guaiacum resin. From these sources it is obtained in colorless, prismatic crystals. These are considered to be absolutely pure guaiacol, and are official in the Paris Codex. The guaiacol of commerce is very variable in strength and often very impure, the impurities being such as are common in creosote and are the result of careless distillation. The adulteration is evident by the lower specific gravity, the stronger odor, and by becoming darker upon exposure. The pure guaiacol, with concentrated sulphuric acid, gives a faint yellow coloration which is changed to a cherry-red by the addition of acetone; the impure article gives a more or less red color with the acid alone.

Guaiacol is absorbed from the stomach or intestines, from the unbroken skin, and by inhalation. It is rapidly excreted and may be detected in the urine, saliva, or perspiration within fifteen minutes. In twenty-four hours it is entirely excreted.

The action of guaiacol is the same as that of creosote, the advantages claimed for it being its greater purity and more definite composition. Locally, it is antiseptic and analgesic, and when administered by the mouth it exercises the same effect upon the stomach and intestinal tract.

Although guaiacol has not replaced creosote in the treatment of tuberculosis, it is very extensively employed and is one of the drugs looked upon with favor in this disease. It has been employed with favorable results in all septic diseases, in puerperal and typhoid fevers, erysipelas, pleurisy, bronchial catarrh, whooping cough, and many local inflammatory conditions.

The method of administering guaiacol varies. Many prefer to give it in continuous small doses, from three to five minims three times a day, while others give it in rapidly increasing doses for the purpose of saturating the system and acting directly upon the pathological processes. With this in view the quantity may be increased by one drop at each dose until fifteen drops, three times a day, are given, and this dose is to be maintained for an indefinite period. It has been demonstrated that as much as sixty minims three times a day may be given without ill effect. When the remedy is given in large doses or when its use is continued for a prolonged period, the action of the kidneys should be watched, as any interference with this function would cause an unexpected retention of the drug in the system.

It should always be administered well diluted, in milk, wine, spirits, or water. The addition of a vegetable bitter, as tincture of orange, gentian, or cardamoms, serves to disguise its taste and to add to its stomachic properties. If capsules are selected they should always be followed with draughts of water or some diluent.

If for any reason the remedy cannot be given by the mouth, enemata may be adopted, and the following formula has proved satisfactory: guaiacol, gr. vij.; sweet almond oil, ℥ iss.; gum acacia, ℥ i.; water, ℥ viij.

Iodoform, eucalyptol, and other similar drugs have been combined with guaiacol for use subcutaneously. Of these iodoform is the most favored. The drugs are dissolved in sterilized oil and injections of iodoform, one-sixth grain, with guaiacol, one grain, are given daily.

Submucous injections have been advised in laryngeal tuberculosis; and inhalations from respirators, or from heated water, have proved of much service.

The absorption of guaiacol through the unbroken skin is very rapid, and advantage is taken of this to obtain its physiological effects. Fifty to sixty minims are applied to the surface, and the part is covered with oil silk. Within fifteen minutes, the pulse relaxes, the skin becomes cool and moist, and the temperature begins to fall. The effect lasts for four or five hours. The application may be repeated night and morning according to the course of the fever. This method of employing the remedy calls for the exercise of care, as the reports of ill effects show that they generally occur when it is used in this way. On account of the rapid absorption of the drug, the fall of temperature may be rapid, descending below normal, with cold extremities, clammy skin, feeble pulse, and other indications of threatened collapse.

Guaiacol Benzoate, "Benzosol": $C_6H_4OCH_3OCOC_6H_5$. A crystalline salt in which one atom of hydrogen is replaced by a benzoyl radical. It occurs in small colorless, tasteless, and odorless crystals, nearly insoluble in water. It contains fifty-four per cent. of guaiacol, and after administration it slowly breaks up into its constituent elements, guaiacol and benzoic acid.

It is given in doses of from five to ten grains, three times a day. It is used in all conditions in which guaiacol is indicated, and is thought to be particularly serviceable in intestinal tuberculosis and diarrhea.

Guaiacol Carbonate, "Duotol": $(C_6H_4OCH_3O)_2CO$, a neutral, white, tasteless, odorless powder. Insoluble in water, containing ninety-one per cent. of guaiacol. In contact with the alkaline secretions of the intestines it breaks up into guaiacol and carbonic acid. The dose is from three to eight grains three times a day. Guaiacol carbonate is the most popular of the guaiacolates, probably from its being extensively advertised as duotol. It has been much used in tuberculosis and in typhoid fever, and as an antiseptic in various intestinal disorders.

Cresotol closely resembles guaiacol carbonate, it being the carbonate of creosote, including guaiacol as well as the other constituents.

Guaiacol Cinnamate, "Styracol": $C_6H_4OCH_2OC_9H_7O$. A German proprietary medicine patented under the latter name. In the intestines it is decomposed into its two constituents, and the beneficial effects of

cinnamic acid, as well as those of guaiacol, are manifested. It, however, has not been much employed.

Guaiacol Piperidin, "Guaiaperol." A compound occurring in granular crystals, soluble in thirty parts of water, with a slight odor of creosote. It has been employed in the treatment of pulmonary tuberculosis and it is thought to possess the stimulating properties of piperidin in addition to the action of guaiacol. Dose: from five to thirty grains.

Guaiacol Valerianate, "Geosote." A liquid combination of guaiacol and valerianic acid, having the characteristic odor of valerian. Dose: five minims in capsules. This preparation has received much attention and is thought to have a particular value as an application in local forms of tuberculosis. It has been used in the Loomis Sanatorium for consumptives and reported upon favorably.

Guaiacol Salicylate; g. phosphate; g. phosphite; potassium guaiacol-sulphonate or "thiocol"; *quinine guaiacol-sulphonate*, or "guaiaquin"; *calcium guaiacol sulphonate*, or "guaiacyl"; and many similar derivatives of guaiacol have been introduced as substitutes for the pure drug. Each one is supposed to add some special therapeutic value, and although all have had some favorable mention, none has attracted much attention or proved of any special value.

BEAUMONT SMALL.
R. J. E. SCOTT.

Guaiacol Cacodylate is a combination of cacodylic acid with guaiacol. It has been recommended hypodermically in doses of gr. ½–1 (0.03–0.06) in tuberculosis. The injection is said to be painless, and the remedy is employed for the purpose of introducing arsenic into the system. R. J. E. S.

Guaiacol-ethyl, homocresol, thanatol, pyrocatechin-mono-ethyl ether ($C_6H_4.OC_2H_5.OH$), is a homologue of guaiacol in which the methyl group is replaced by ethyl. It is an oily liquid, insoluble in water or glycerin, and soluble in alcohol, ether, and chloroform. It resembles guaiacol physically and physiologically, but has a greater analgesic and sedative action. It has been used for neuralgia, neuritis, painful joints, epididymitis, etc., in ten to fifty per cent. ointment. In tuberculosis it has been employed in place of guaiacol in doses of ♏ 5–10 (0.3–0.6) three times a day in milk or in capsule.

R. J. E. SCOTT.

Guaiacum.—GUAIAC, *Guaiaci Resina, Guaiac Resin.* The resin of the wood of *Guaiacum officinale* Linne or of *G. sanctum* Linne (fam. *Zygophyllaceæ*). The heart-wood of the same trees was also formerly official. These are small evergreen trees of northern South America and the West Indies, having the habit of a small apple-tree, and forming a brilliant mass of bright blue, when in full bloom.

Guaiacum wood was carried to Europe soon after the discovery of the West Indies (early in the sixteenth century), and made a rapid reputation for itself as a remedy for syphilis and gout, a reputation that it unfortunately very soon lost again in great measure. Two products of the tree are imported—the wood, which if of fair size and soundness, goes to the turners to be made into pulley-sheaves, mallets, mortars, tool handles, etc., and the crude resin, rudely obtained from the living tree or fresh wood.

The wood comes in logs several feet in length, and from two to six or eight or more inches in diameter, often irregularly crooked and branching; they consist, excepting the smallest, of a bright yellow, hard *alburnum*, and a very dark greenish-brown, exceedingly hard and heavy heart, consisting of very much thickened wood cells, and an abundance of a peculiar composite resin. This wood is almost as hard and heavy as ivory, and turns the edges of tools not especially sharpened for it. That which reaches the drug market consists principally of the turnings and refuse of what is manufactured for the purposes above named. It should consist only of the brown or green heart-wood, which is heavier than water, to which it does not impart its color. Upon the addition of nitric acid, if it has not been deprived of its resin, it should give a dark, bottle-green color. The resin, of which there should be about twenty-five per cent., is the only active constituent, so that its properties are also those of the wood.

The resin, which is obtained partly by incising the trees, and partly as a spontaneous exudation, also sometimes forced out from the wood by heat, is a crude and impure substance. It occurs in irregular masses, or subglobular pieces, externally greenish-brown, internally of a glassy luster, and, in recent guaiac, usually reddish-brown, transparent in thin splinters, fusible, feebly aromatic, the odor becoming stronger on heating; taste somewhat acrid; powder grayish, turning green on exposure to air.

Soluble in potassium or sodium hydrate T. S. and in alcohol; the alcoholic solution is colored blue on the addition of tincture of ferric chloride.

It is very brittle when cold, plastic with slight heat.

COMPOSITION.—It contains about seventy per cent. of *guaiaconic acid*, a yellow or brown, brittle, amorphous resin; ten of *guaiaretic acid* which is crystalline; nine or ten of *guaiacic acid*, something like guaiaconic acid, and three or four of gum, besides a little volatile oil, ash, coloring matter, and various impurities.

ACTION AND USE.—The reputation of guaiac depends upon clinical evidence entirely, and has had spells of waxing and waning. It is stimulating, or in large doses irritating to mucous membranes, and markedly increases their secretions, thus acting as a laxative. Its medicinal value depends practically upon its pronounced stimulation of the eliminative functions. The high estimate early placed upon it in syphilis has disappeared since the real efficiency of mercury and iodine has been established. In gout, although perhaps useful, it is certainly no specific; as an emmenagogue it is no better nor worse than many others. In chronic and mild subacute rheumatism, and in rheumatic arthritis, the evidence in its favor is strong. It is perhaps one of the best remedies for these intractable maladies. It is considerably used in inflammatory conditions of the throat and fauces, especially when there is deficient secretion.

ADMINISTRATION.—The dose of guaiac (resin) is from gr. viij. to gr. xxx. (0.5 to 2.0). It may be given in pill or powder, but the tinctures, of which there are two—one simple (*Tinctura Guaiaci*, U. S. P., strength twenty per cent.), made with alcohol, and one associated with ammonia (*Tinctura Guaiaci Ammoniata*, U. S. P., strength twenty per cent.), made with aromatic spirit of ammonia—are more generally used in doses fl ℥ ss.–i. (2.0–4.0). Both become turbid upon mixing with water, and are oftenest given in milk. Guaiac wood is used as an adjuvant in the Compound Syrup of Sarsaparilla. H. H. RUSBY.

Guaiamar, the glycerol ester of guaiacol ($C_6H_4.OCH_3.OCH_2.CHOH.CH_2OH$), is formed by the action of anhydrous glycerin on guaiacol. It is a white, dry, crystalline powder, soluble in twelve parts of water, and in alcohol, chloroform, ether, and glycerin. It has a bitterish, aromatic taste, and is split in the alimentary tract into guaiacol and glycerin. It is said to be antipyretic, diuretic, diaphoretic, and antiseptic. It stimulates the appetite and prevents gastric fermentation, deodorizes and loosens the bronchial excretions, and is a very efficient antiseptic to the alimentary or genitourinary tract. It is less irritating than benzosol or guaiacol carbonate, though occasion-

ally more so by idiosyncrasy. Butler recommends it in typhoid fever, tuberculosis, bronchitis, bronchopneumonia, chronic cystitis, gonorrhea, and the summer diarrhea of children. Its dose is 0.2–1 gram (gr. iij.–xv.). Locally, with belladonna and mercurial ointments, he applies it to rheumatic joints; and, with balsam of Peru and zinc ointment, to bed-sores.

W. A. Bastedo.

Guaiasanol, di-ethyl-glycocoll-guaiacol hydrochloride, occurs in the form of white prisms, having a faint odor and a saline, bitter taste. It is freely soluble in water. It liberates guaiacol in the alimentary tract, and has been used both externally and internally for the same purposes as guaiacol. The dose is gr. 15–30 (1.0–2.0) three times a day. It may be used hypodermically, and in two-per-cent. solution is unirritating to wounds.

R. J. E. Scott.

Guanase is an enzyme having a diaminizing action upon guanine whereby this substance is converted into xanthine.

F. P. U.

Guanidine.—This substance, $C(NH_2)_2{=}NH$ is closely related to cyanamide and may be formed from guanine. It possesses interest from its relation to urea and from the fact that it occurs in proteins as arginine. The guanidine groups of the proteins are considered as the mother substances of creatine and creatinine.

F. P. U.

Guanine.—Guanine, $H_2N{-}C_5H_2N_3O$ (2 Amino-6-oxypurine), is present in all organs containing large quanties of cells, and also in the urine in small quantities. Under pathological conditions it has been found in the blood in leucemia. By the action of an enzyme guanase, it is converted in the body to xanthine which is then transformed to uric acid in which form it may be eliminated. It is insoluble in water, alcohol and ether, but is readily soluble in mineral acids and alkalies with the exception of ammonia.

F. P. U.

Guanasine is a glucoside-like combination of guanine and a pentose (d-ribose) contained in guanylic acid as a compound with phosphoric acid. Guanosine belongs to group of bodies designated as nucleosides from their derivation from nucleic acids and their properties of a glucoside-like nature.

F. P. U.

Guarana.—(Pronounced *gwaw-rah-nah'*.) "A dried paste, consisting chiefly of the crushed seeds of *Paullinia cupana* Kunth (fam. *Sapindaceæ*), yielding when assayed by the following process, not less than 3.5 per cent. of its alkaloidal principles." (U.S.P.). This is a climbing shrub, native of the hottest parts of South America, but the seeds are obtained wholly from cultivated plants.

The genus contains upward of one hundred and twenty species, and its members are rich in saponin, also contained in guarana, on account of which parts of several of them are used as fish-poisons.

The guarana plant is very extensively cultivated, especially upon the banks of the Itenez River, a southern tributary of the Madeira. It is grown to stout stakes or poles and the plantation resembles an ordinary vineyard or hop-field. The panicles of small white flowers are succeeded by fruit clusters looking not unlike large bunches of immense grapes. When ripe, the yellow fruit splits into three husks and the seeds are lost. They are gathered just previous to this time and the seeds are shelled and washed. The seed is large (one centimeter in diameter), globular or spheroidal, with a flattened base, and a slightly pointed summit. Its surface is dark-brown and very shiny, excepting the large chalaza at the base, which is light-colored, and, before it is disturbed, covered with a large aril. It is exalbuminous and entirely filled by the large fleshy embryo. In general appearance and structure it may be described as a small horse-chestnut. After shelling, the seeds are lightly roasted, by which the testa is loosened. The latter is then broken off and winnowed out, and the kernels are coarsely broken up in a wooden mortar and with a wooden pestle. Just enough water is added to form an adhesive mass. This mass is then moulded by hand into cakes, balls, or, more commonly into sausage-shaped rolls, six to ten inches in length by one or two in diameter. The drying of these is the most delicate and critical part of the operation. It is conducted by artificial heat, in specially built houses, great care being taken to avoid a disagreeable flavor from the smoke or from the subsequent development of some variety of mould through imperfect or unequal drying. Adulteration occurs only occasionally. It consists in making various additions— usually tapioca starch—to the mass before it is subjected to the drying process.

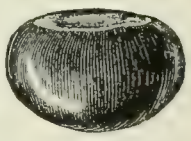


Fig. 2837.—Paullinia Seed. Natural size. (Baillon.)

As regards the home consumption of guarana, it is the exact equivalent of tea or coffee, except that it is grated off and taken suspended in cold water. It is the staple beverage of millions of people. Its excessive habitual use brings on nervous disorders similar to those from other caffeine-containing beverages, and ending in a kind of palsy.

Description.—In subglobular or elliptical cakes or crylindrical rolls, hard and heavy; outer surface somewhat shortly nodular, smooth, slightly lustrous, deep chocolate-brown; rather brittle, the fracture uneven, often fissured in the center, of a deep flesh color or pale reddish-brown, showing numerous coarse, angular, lustrous fragments of seeds partly invested with blackish-brown integuments; odor slight, peculiar, a little resembling that of chocolate; taste very astringent, somewhat bitter, afterward sweet, especially when chewing is followed by the taking of a swallow of water.

Composition.—Guarana stands at the head of caffeine-yielders, containing four or five per cent. A quarter of its weight is tannin, and there are starch, saponin, resin, and small amounts of fixed and volatile oil. It should not yield more than two and one-half per cent. of ash. It should be remembered that the domestic value of guarana depends largely upon its flavor. Many lots defective in this particular are exported for medicinal use and are not necessarily inferior for this purpose. At the same time, adulterated lots are undoubtedly manufactured especially for such export, but only rarely.

Action and Medicinal Use.—Because of its tannin, guarana is to be compared rather with tea than with coffee. Caffeine is elsewhere so fully treated that its action cannot be here discussed.

As the contained dose of tannin is a small one, it is, in fact, a mode of giving caffeine, and little or nothing more. Its principal clinical reputation lies in its value

in nervous and sick headaches, of which there is considerable evidence. It has been the foundation of several widely known secret remedies for these afflictions.

The powdered drug can be given in gram doses or more, repeated once an hour, until the headache is relieved, or until several doses have been given. The fluid extract (*Extractum Guaranæ Fluidum*, U.S.P.) is rather neater, and of the same theoretical strength. Milk is a good vehicle for either.

HENRY H. RUSBY.

Von Gudden, Bernhard Aloys.—Born in Cleve, Germany, on June 7, 1824. He pursued his medical studies at the universities of Bonn, Berlin, and Halle, and received the degree of Doctor of Medicine from the latter institution. From 1849 onward he devoted himself to the study of psychiatry, first under Max Jacobi in Siegburg, and then under Roller in Illenau. From 1855 to 1869 he was Physician-in-Chief of the Insane Asylum at Werneck, in Lower Franconia. In the latter year he was called to Zürich, to fill the chair of Psychiatry in the University of that city. In 1872 he was appointed Professor of Mental Disorders in Munich, with the added title of Obermedizinalrat; and at the same time he was given the position of Director of the principal insane asylum of the district. Fourteen years later (June 13, 1886) he lost his life in an attempt to save that of his patient, the insane King Louis II of Bavaria who had thrown himself, with suicidal intent, into the Starnberger Lake not far from Munich.

Von Gudden, according to Pagel, was one of the most gifted and influential of the psychiatrists of modern times. His published writings on the various experiments which he made in relation to the growth of the calvarium, localization in the cortex of the brain, etc., deserve special commendation. In addition to these, however, he wrote a large number of shorter treatises on psychiatric topics, a collection of which has been published by Hubert Grashey under the title of Gudden's literar, Nachlass.

A. H. B.

Guéneau de Mussy, Henri.—Born in 1822. In 1844 he received the degree of Doctor of Medicine, his thesis bearing the title "De l'apoplexie pulmonaire." Having first gained a certain amount of hospital experience he accompanied the king, Louis Philippe, into exile. After the latter's death in 1850 Guéneau de Mussy continued to reside in England up to the year 1871, when he again took up his residence in Paris. He was a member of the College of Physicians in London, and also of the Academy of Medicine in Paris. He died in Saint-Raphaël early in October, 1892.

Of his published writings the following deserve to be mentioned: "The History of the Case of Poisoning by Lead, which lately occurred at Claremont, with Observations, etc.," *Dublin Quart. Jour.*, 1849; and "Aperçu de la théorie de germs contagieux; de l'application, de cette théorie à l'étiologie de la fièvre typhoïde, etc.," Paris, 1877. A. H. B.

Guenther, Johann.—A German physician who flourished during the sixteenth century, and who is chiefly celebrated for the work which he did in reviving the knowledge of Greek medicine and for his able and zealous advocacy of the importance of studying anatomy. Johann Guenther was born in 1487 at Andernach on the Rhine, not far from Cologne. Having manifested a decided love of study at an early period of his boyhood he was sent in 1499 for his further education to the University of Utrecht, Holland. Here he devoted himself more particularly to acquiring a thorough knowledge of Greek. From Utrecht he went first to Deventer (about forty miles to the east of Utrecht)and then to Marburg in Hesse Nassau, Germany. In the university of the latter city he also studied philosophy and the science of physics. A few years later he was appointed Professor of the Greek language at the University of Louvain, in what is now Belgium, the celebrated Vesalius being one of his pupils in this institution. A preference for the study of medicine having by this time asserted itself quite strongly Guenther visited Paris, the city in which, more than in any other town of Europe during the early part of the sixteenth century, this branch of knowledge was greatly cultivated. He read here, with profound interest, the works of the Greek physicians, and made translations of several of their writings, more particularly those of Hippocrates and Galen. He received his doctor's degree on October 29, 1531, and five years later he was appointed one of the household physicians of Francis I. Then, during the period immediately following, he cultivated the study of human anatomy and gave public courses of instruction; Sylvius, Vesalius, and Rondelet being among his pupils. At the same time he was not neglectful of the other important branches of medical knowledge—surgery, botany, chemistry, and internal diseases. From Paris Guenther went to Strassburg, where he expounded for a certain length of time the works of the ancient Greek writers. Then he devoted himself for a number of years to the practice of his profession, his services being called into requisition by people living in almost every part of Central Europe. Toward the end of his career he received various titles of nobility. He died October 4, 1574, at the age of eighty-seven.

Guenther's published writings are of two kinds—translations of the best medical authorities of ancient times, and his own original compositions. Of the former class the following deserve to receive special mention: "Anatomicarum institutionum secundum Galeni sententiam libri iv," Basel, 1536; "De victus et medendi ratione, tum alio, tum pestilentiæ maximæ tempore observanda, commentarius, etc.," Strassburg, 1542; and excellent translations of Polybus, Paulus Aegineta, Oribasius, Rhazes, Alexander of Tralles, and Coelius Aurelianus. From his own compositions the following selections may be made: "De medecina vetere et nova, tum cognoscenda tum faciunda, commentarii duo," Basel, 1571; and "Gynæciorium commentarius de gravidarum, parturientium puerperarum et infantium cura," Strassburg, 1606.

A. H. B.

Guernsey.—See *Channel Islands*.

Guersant, Paul Louis Benoît.—Born in Paris, France, in 1800. He received his doctor's degree in 1828, his thesis bearing the title: "Sur les avantages et les inconvéniences de la lithotomie, comparés à ceux de la lithotritie." In 1832, after a somewhat severe competitive examination, he was made Surgeon of the Children's Hospital. The usefulness of this institution was soon much increased by Guersant's establishment of a surgical policlinic as a part of the regular work of the hospital. In 1860, after twenty-eight years of service, he resigned his position in the Children's Hospital. In the meantime the policlinic had attracted a constantly increasing number of students, both Frenchmen and foreigners. Guersant was one of the seventeen surgeons who, in 1843, founded the Société de Chirurgie of Paris, and during the year 1852 to 1853 he was chosen its president. He died October 1, 1869.

Guersant's published writings, which were quite numerous, dealt almost exclusively with the surgery of children. One of them entitled "Notices sur la chirurgie des enfants," Paris, 1864 to 1867, was translated into English by Richard J. Dunglison, Philadelphia, 1873. A. H. B.

Guinea-worm.—A round worm, *Filaria medinensis*, also known as dracunculus, Beinwurm, Brachwasserwurm, tank worm, and dragon-neau, which is endemic in many tropical countries. It enters the human body by drinking in a small fresh-water crustacean, *Cyclops*, and causes dracontiasis, in which the adult is found in the connective tissue beneath the skin. See *Nematoda*. A. S. P.

Guja.—Epidemic spasmodic bronchial asthma. The word *guja* (pronounced goo'hah) is from the Chamorro, the language of the natives of the Mariana Islands. The following description of the disease is taken from the sanitary report of the senior medical officer in the island of Guam to the Surgeon General of the Navy for the year 1904. The total population of Guam at that time was 10,355.

"This disease is unusually prevalent in Guam. It affects natives at all ages. The intelligent ones among them attribute it, probably correctly, to sudden changes in the atmospheric conditions. The atmosphere has always a high humidity. Sudden wide-spread epidemics of this trouble occur, generally at the change of seasons about July and November, when the trade wind gives place to the south-west monsoon or *vice versa*. Within forty-eight hours hundreds of persons will be suddenly afflicted, many dangerously, a considerable number fatally. The symptoms and signs are simply those of spasmodic bronchial asthma without catarrh or fever and with labored but otherwise normal heart action. The disease has been mistaken for influenza, but the entire absence of fever precludes such a diagnosis.

"The *symptoms* are just those generally seen elsewhere in asthmatics at or after middle life. All ages are affected, from six months to four-score years. Within a week, with a change of weather, the whole epidemic subsides and those that have not died are well, except for traces of emphysema after repeated attacks. As the mortality table for the year shows, twenty-seven out of 191 deaths from known causes, or more than fourteen per cent., were from this disease."

The *treatment* is symptomatic and palliative.

J. F. Leys.

Gull, William Withey.—Born in Thorpe-le-Soken, County of Essex, England, December 31, 1816. He pursued his medical studies partly at Guy's Hospital and partly at the University of London, and received the degree of Doctor of Medicine from the latter institution in 1846. For a period of twenty years he was Attending Physician and Instructor in Medicine at Guy's Hospital. From 1847 to 1849 he was Fullerian Professor of Physiology in the Royal Institution of Great Britain. He was a member of the General Medical Council. The honorary degree of LL. D. was conferred on him by Oxford in 1868, by Cambridge in 1880, and by Edinburgh in 1884. In 1872 he was created a baronet. He was also Physician Extraordinary to the Queen, Physician-in-Ordinary to the Prince of Wales, and Consulting Physician of Guy's Hospital. He died January 30, 1890.

Sir William Gull's researches in the domain of diseases of the nervous system deserve honorable mention in the history of clinical medicine. His active support of the temperance movement in England is also something which should be set down to his lasting credit. Of his published writings the following deserve to receive special mention: "Goulstonian Lectures on Paralysis," *London Medical Gazette*, 1849; "Abscess of the Brain," in Reynolds' System of Medicine; "Paraplegia," in Guy's Hospital Reports, 1856, 1858; "On Paralysis of the Lower Extremities Consequent upon Disease of the Bladder and Kidneys (Urinary Paraplegia)," Guy's Hosp. Rep., 1861; and (in association with Sutton) "Arterio-capillary Fibrosis," in Medico-Chirurgical Transactions, vol. iv. A. H. B.

Gum Arabic.—See *Acacia*.

Gumma.—See *Syphilis*.

Gums.—See *Active Principles*.

Gums, Diseases of.—See *Mouth, Diseases of*.

Gunshot Wounds.—To the surgeon in civil communities gunshot wounds are understood to result from missiles fired from portable hand weapons such as shotguns, sporting rifles, pistols, revolvers, toy-pistols, air guns, etc. These weapons propel projectiles like bullets of varying caliber, lead pellets, powder grains, wadding, etc., by means of an expansive force which is produced by the sudden liberation of large volumes of gases by igniting or detonating explosive materials. The term gunshot wounds has a much wider application for the military surgeon. To him the term includes in addition to those already specified, all wounds which result from the effects of any explosive force. In his battle returns under the term "gunshot wounds" he includes all traumatic injuries which are caused by projectiles from firearms generally, viz., shotguns, sporting rifles, pistols, revolvers, toy-pistols, air guns, cannons, bombs, terrestrial mines, torpedoes, or any implement used in war. In medico-military parlance we may also add that any particle of matter such as a splinter of wood, piece of mortar, sand or gravel that is set in motion with sufficient velocity by a sudden expansive force may cause a gunshot wound.

Firearms.—To understand properly the characteristic features of wounds caused by projectiles the surgeon should acquaint himself in a brief way at least with the different kinds of firearms, their projectiles, the nature of the explosives which are used to propel them, and the ballistics of projectiles as this relates to motion, velocity, and energy.

In the military service firearms are divided into the artillery class and the so-called hand weapons. The former includes large guns, field guns, and other devices used in war.

Large guns are now breech-loading rifle guns. They are used on board ship and on fortified positions. The largest of these guns are sixteen inches in caliber, forty-nine and one-fourth feet in length, weighing 130 tons. Their projectiles are made from the hardest steel, each weighing 2,400 pounds with an initial velocity of 2,250 f.s.

Mobile artillery and *siege guns* vary in caliber between three and six inches. The former accompanying an army in the field and the latter are used against fortified positions and they both employ shell and shrapnell.

Howitzers are shorter than the field guns, of 3.8 to 4.7 inches in caliber.

Mortars are still shorter. They are used to throw projectiles into fortified positions and onto decks of vessels.

Service machine guns are now extensively used by all armies. They employ the ammunition of the military rifle of the line, which they fire at great speed.

Hand Weapons.—This class of firearms is fired from the hand or shoulder. It includes the military rifle, revolver, and pistol.

The Military Rifle.—This is the weapon carried by all soldiers of the line. In its present state of perfection it has been evolved from the hand-cannon, the handgun, match lock, the flint lock, percussion-cap, smooth bores, and rifled guns. The earlier guns mentioned were larger in caliber, ranging between 0.63 and 0.75. They fired bullets made of soft lead weigh-

ing from 315 to 400 grains and the charge of powder was from 130 to 270 grains. The projectiles were round with initial velocities ranging from 540 to 950 f.s., and the effective range never exceeded 350 yards. The guns referred to were all loaded by the muzzle and the more perfect of them is represented by the Springfield rifle which was adopted by the U. S. Army in 1855. Its caliber was 0.58 inch, weight of bullet 500 grains, charge of powder sixty grains, and the rifling in the barrel made one complete turn in thirty-six inches. Our army used this rifle until 1866. At this time we reduced the caliber to 0.50 inch and converted the Springfield rifle into a breech-loader. In 1873 we still further reduced the caliber to 0.45 inch, the twist was shortened to one turn in twenty-two inches to give the elongated bullet more stability, the powder charge was placed at seventy grains and the weight of bullet at 405 grains. The velocity of the bullet was now 1,315 f.s. with a point blank range of 350 yards, and a maximum effective range of 2,000 yards. In expert hands this weapon could be fired as often as twenty shots per minute. It was one of the effective weapons of its time and its ballistic value was equal to the German Mauser, the Lee-Speed of the English, and the Lebel of the French, etc. With but slight modifications we continued to use the Springfield rifle until 1892 when we adopted a magazine breech-loading rifle with reduced caliber under the name of the Krag-Jorgensen rifle, with features as follows:

Caliber	30 m.
Twist, turn	1 in 10 inches.
Weight of bullet	220 grains.
Bullet:	
envelope	cupro-nickel steel.
core	lead and tin.
Smokeless powder (nitrocellulose)	35–42 grains.
Initial velocity	2,000 f.s.
Muzzle energy	1,954 foot-pounds.

This gun corresponded in effectiveness for war with the guns of foreign nations which were in use at about this time. In 1903 we perfected and adopted a new arm very much on the lines of the German Mauser of reduced caliber which we called the United States rifle, cal. 0.30, model 1903, in which the length of barrel was reduced to 24.006 inches. Again in 1906 we made radical changes in the ammunition: the weight of bullet was reduced from 220 to 150 grains. The ogival head of the bullet was brought to a point to reduce the resistance offered by atmospheric air, and the powder charge was increased from thirty-eight to fifty grains. The muzzle velocity of the rifle bullet has been increased from 2,000 to 2,700 f.s., and the striking energy from 1,954 to 2,400 foot-pounds. The extreme range has been increased from 4,066 to 4,891 yards. The rapidity of fire has been increased to twenty-three aimed shots per minute when the rifle is used as a single loader, and to thirty shots in the same time, when the piece is pointed from the hip, without aim. The bullet penetrates 28.25 inches in thoroughly seasoned oak across the grain at fifty feet as compared to 3.2 inches and 19.5 inches by the bullets of the Springfield and Krag-Jorgensen rifles at the same distance. The trajectory of the bullet is flatter and the danger space has increased for all the ranges. The point blank danger space while firing in different positions is as follows:

Firing standing	718.6 yards.
Firing kneeling	629.4 yards.
Firing lying down	589.7 yards.

In many respects this is one of the most effective guns used by any army. The bullet's center of gravity is placed near its base, a fact which gives it but little stability in flight. When it hits structures having the slightest resistance it is apt to turn and assume a position at a tangent to its line of flight. The effect of this instability on the wounds it causes will be discussed later.

The other hand weapons to be considered are the shotgun, revolvers and pistols, the toy-pistols, and so-called Flobert rifles. With the exception of revolvers and pistols we will not refer to these weapons until we are discussing their projectiles later on as their mechanism and uses are sufficiently familiar to American readers at least.

Revolvers and Pistols.—We have to mention these weapons specially because of the late changes which have taken place in the use of a class of weapons that is so generally employed among people in personal combat and in which changes have recently been made in the military service. The more familiar examples of revolvers in this country are the Smith and Wesson, and the Colt's new service revolvers. The Colt's revolver is a double action weapon which can be fired separately by cocking the hammer and pulling the trigger or, when rapidity of action is required it may be fired by a steady pull on the trigger. The United States Army used this weapon for many years, but its stopping power was found deficient, and it lacked also in accuracy of fire. The United States Army has recently conducted many trials of automatic pistols so-called, viz., the Savage, Luger, and Colt's, of calibers ranging from 0.32 inch to 0.45 inch with most favorable results, after which the 0.45 caliber Colt's automatic pistol was adopted in lieu of the 0.38 caliber Colt's new service revolver. The fact that automatic pistols are fast supplanting the use of revolvers in and out of the military services requires a more specific reference to their mechanism and ballistic qualities. The wounds caused by their projectiles are much more severe than those caused by the ordinary revolver bullets, and this fact makes the advent of these weapons of special interest to civilian practitioners and military surgeons alike.

Colt's Automatic Pistol.—This pattern of automatic pistol has a movable barrel and slide the recoil of which ejects the empty shell, cocks the firing mechanism and loads a new cartridge into the barrel. When the first shot has been fired it is only necessary to make a steady pull on the trigger for each succeeding shot until the magazine is emptied. The magazine holds seven cartridges in the 0.45 caliber weapon and eight cartridges in the 0.32 and 0.38 caliber weapons. The bullet weighs 200 grains in the largest caliber, it is composed of a lead core placed in a steel jacket. Nitrocellulose is used as a propellant, and the initial velocity is 900 f.s. The advantages of this weapon over the Colt's revolver is said to consist in greater accuracy, less recoil, greater rapidity of fire, rapidity of loading and a greater number of shots. Reloading is done by inserting an extra magazine from below in the hollow handle.

Explosives.—The effectiveness in present day firearms is largely due to the use of modern explosives. These substances are used to propel projectiles into space, to explode shells, mines, fugases and bombs, torpedoes, etc., in offensive and defensive warfare.

Gun Powder.—This was the only explosive used in war for centuries. It is usually referred to under the name of black gun powder, and it is formed by the mechanical mixture of saltpeter 75 per cent., charcoal 15 per cent., and sulphur 10 per cent. Its value as a propellant is due to the large amount of gas which it liberates on exploding. It is usually exploded in hand weapons by striking the primer in the base of the metallic cartridge which is charged by fulminate powder. The results of the explosion are 43 per cent. gaseous products and 57 per cent. of unburnt powder grains which are propelled forward as projectiles, and cause the familiar example of tattoo or powder burn on the skin. The volume of the gases at freezing temperature and under atmospheric pressure, occupies 280 times the bulk of the original charge. When

the explosion occurs in a vessel completely filled by the powder, the pressure exerted as a result of the liberation of the gaseous vapors is 5,850 atmospheres (Noble and Abel). The temperature of the flame at the moment of ignition has been estimated at 2,000° F. to 4,000° F. a fact which is no doubt responsible for the erroneous notion that the heat imparted to projectiles from this great amount of temperature renders bullets sterile on impact. In the explosion which takes place the niter furnishes the oxygen and the charcoal furnishes the carbon while the sulphur adds to the rapidity of the explosion.

Modern Explosives.—These have many uses in the industrial world, but to surgeons they are of chief interest when used in the discharge of firearms and other engines of destruction in peace and war.

Fulminate Powder.—Among the modern or so-called high explosives, fulminate of mercury takes first rank. It is the only one of the fulminates used in firearms. It explodes instantly with great force by either friction or percussion. It is the most typical among the detonators because of the rapidity of its explosion. It is used as a detonator in exploding gun-cotton and other explosives, and also in charging percussion caps. It is handled with impunity when wet, in which state it burns quietly in the open air. When heated to 360° F. it explodes with characteristic violence. The theoretical pressure developed by the explosion is 28,000 atmospheres and the gases of the explosion are CO_2, N, and a vapor of mercury. In the attempt to assassinate the French Emperor in 1858 three bombs were exploded each containing four ounces of the mercuric fulminate, when 511 wounds were inflicted on 156 persons. The large number of multiple wounds testify to the violence of the explosion.

Smokeless Powders.—These powders emit no smoke on exploding hence their name. Their composition is better known now than formerly. Our military services use two classes of smokeless powders, viz., nitroglycerin and nitrocellulose powder. They are both made from gun cotton, but the nitroglycerin powder has in addition from ten to thirty per cent. of nitroglycerin which increases the temperature of the explosion, thereby adding to the erosion of the large guns. For this reason the nitroglycerin powder is seldom used except in the hand weapons, while the use of the nitrocellulose powder is confined to the large guns. The following is the composition of one of the nitroglycerin powders:

Insoluble nitrocellulose	67.25 per cent.
Nitroglycerin	30.00 per cent.
Metallic salts	2.75 per cent.

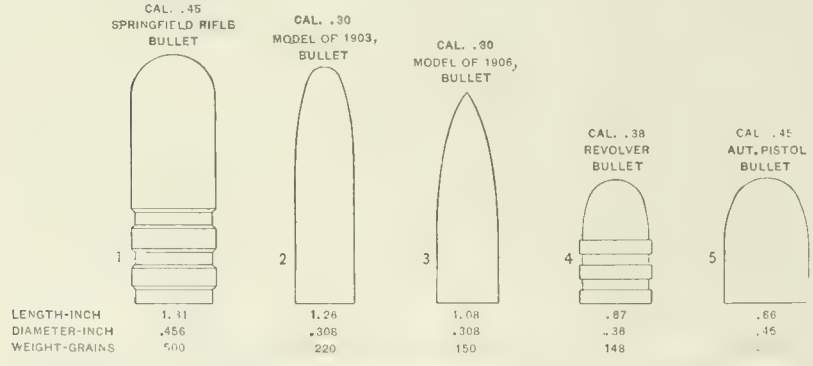


Fig. 2838.—Nos. 3 and 5 represent the shape and size of the rifle and pistol bullets in present use by the United States Army. 1, 2, and 4 represent the rifle and revolver bullets recently discarded.

Forty pounds of acetone is the solvent for 100 pounds of the above mixture. The paste thus made is shaped and cut into bead-like grains, perforated and graphited. The nitrocellulose powder is composed of gun-cotton containing 12.65 per cent. nitrogen dissolved in two parts of ether to one of alcohol. It is prepared very much like the nitroglycerin powder but not graphited. The grains are brown in color and their size differs with the caliber of the gun.

The principal advantages in the use of the smokeless powders are that they are almost entirely converted into gas; with smaller charges it is possible to give higher velocity to the projectile; it leaves no residue in the bore; the theoretical pressure when

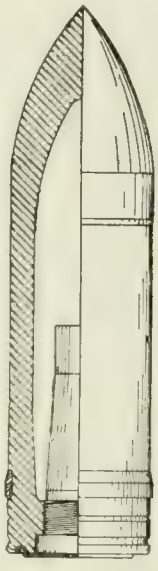


Fig. 2839.—The 3-inch Common Steel Shell used in U. S. Army.

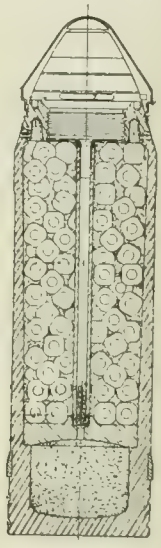


Fig. 2840.—Common Shrapnel used in U. S. Army.

exploded in its own volume exerted by gun-cotton is 24,000 and as much as 25,000 atmospheres for nitroglycerin, viz., four times greater than the pressure developed by the explosion of the old black gun-powder.

There are other smokeless powders with picric acid as a base which interest the surgeons because of the irritating fumes which they emit. They are popularly known under the names of melinite, emmensite, liddite, etc.

Projectiles.—The term projectile is synonymous with the term bullet when it refers to projectiles from hand weapons. Objects propelled from the bursting charge of grenades, bombs, and mines are also referred to as projectiles.

Projectiles from hand-weapons are shot from rifles, pistols, and revolvers, shotguns, air-guns, etc. These projectiles or bullets are classed as follows: penetrating, setting up, disintegrating, and explosive bullets. The penetrating bullets are the steel-jacketed bullets commonly used in reduced caliber rifles and automatic pistols. The setting up bullet is composed of lead to invite deformation against resistant tissues. The disintegrating, sometimes called Dum-Dum or metal-patched bullets, are composed of a core of lead enveloped in a steel jacket except at the point or nose of the bullet. Such a bullet readily breaks into fragments of

steel and lead on impact against resistant structures like bone. Explosive bullets are hollow lead bullets containing an explosive which is made to explode by a cap arrangement placed in the nose of the projectile. They are seldom used now.

Projectiles from pistols and revolvers are usually shorter and weigh less than the bullets of military rifles. (See Fig. 2838.)

Shotgun projectiles or pellets are all round and composed of hard lead. They vary from 2,020 to the troy ounce to buck shot which are 0.31 inch in caliber. The smallest pellets weigh a fraction of a grain, and the buck shot weigh as much as thirty-eight grains. The number of pellets in a cartridge depends on the bore of the gun and size of the pellets.

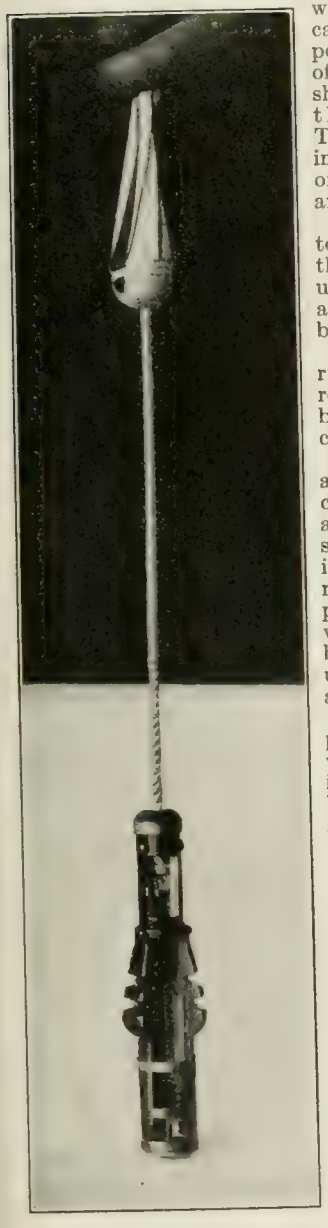


Fig. 2841.—Grenade in the U. S. Service.

The projectile of the toy pistol consists of the entire charge made up of cardboard wad and about six grains of black powder.

Airgun and flobert rifle projectiles are round or elongated lead bullets of about 22 caliber.

Projectiles from the artillery arms are classed as shot, shell, and case-shot. Solid shot is no longer used in modern guns. Shot now consists of a hollow projectile with thick walls, provided with a bursting charge. It is used to perforate armor and against material.

The *shell* is a hollow projectile with thinner walls than the preceding. It holds a larger bursting charge and it is used against bodies of troops or material. (See Fig. 2839.)

Canister and *grape-shot* consisted of a number of shot held in a case which was made to burst by the shock of discharge or impact. They are no longer used.

The modern *shrapnell* has taken the place of the latter. It is becoming more generally used in battle and because of the severe character and number of wounds which it inflicts it is of special interest to surgeons. In the Turko-Balkan War of 1912–13 the casualties in some of the battles from shrapnell balls alone ranged from thirty to eighty per cent. The projectile is a steel tube provided with a time fuse, fired from a three-inch field gun. It is ten inches long and weighs fifteen pounds. Its initial velocity is 1,700 f. s. and it is a man killer at 6,500 yards. The projectile contains a bursting charge and 252 round lead balls 0.50 inch in caliber, weighing 167 grains each. When bursting within 3,000 yards the area of dispersion of the contained projectiles extends for a length of 400 yards and a width of 150 yards (Fig. 2840).

Grenades, Bombs, Mines, and Torpedoes.—In addition to the projectiles of the foregoing weapons, gunshot wounds are inflicted in war by the bursting of the foregoing instruments.

Grenades.—The grenade is an old explosive projectile the use of which was revived in the Russo-Japanese War. The hand grenade of the Japanese consists of two parts, the body and handle The body, a tin cylinder, is four and one-half centimeters in diameter by six centimeters in length filled with shimose-powder and it is provided with a time fuse. The grenade in our service is very similar to

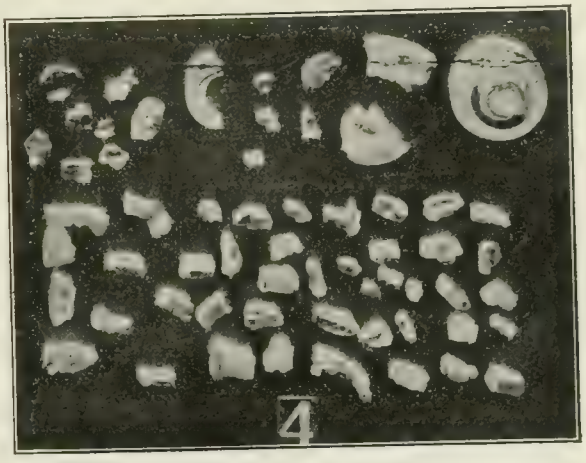


Fig. 2842.—Fragmentation of a Grenade.

the Japanese grenade except that the body is made of steel (Fig. 2841). The grenade is fired from the rifle instead of by hand. When exploding the projectile breaks into many small fragments of steel and the violence of the explosion is capable of killing men and destroying material. (See Fig. 2842.)

Hand bombs were extensively used by both combatants in the Russo-Japanese War at Port Arthur. The Japanese bomb was composed of fourteen pounds of a mixture of pyroxylin and melinite placed in linen bags which were provided with a time fuse. The bags were suspended from the soldier's neck, and they were thrown among the enemy at opportune moments. The Russians employed a device quite similar. The container for the high explosive was their discarded three-inch copper shells which was provided with a fuse and thrown by hand also.

Mines and torpedoes as engines of war are used in naval and harbor defences. The land forces employ terrestrial mines composed of a quantity of one of the high explosives confined in a case, at certain intervals, under ground. These can be exploded at will by electric connections from a central point. Troops advancing on a terrain so mined are blown up by the rapidly displaced air at or near the vicinity of the explosion, or otherwise injured, by projectiles composed of dirt, gravel, and pieces of the casing containing the explosive.

Gatling and Automatic Machine Guns.—The projectiles from these weapons are similar to the bullets used in the military rifle since the cartridge used by them is the same and the wounds caused by either weapon have the same characteristic features.

Ballistics.—*Motion of Projectiles.*—Two motions are imparted to bullets as they leave the muzzle of

the gun, viz., a motion of translation and a motion of rotation. In the case of the spherical balls used in the earlier types of hand weapons the motion of rotation was one more of accident than design. It was a motion of rotation on an axis at right angles to the line of flight of the bullet; its velocity was variable, and the direction of rotation was marked by the last point of contact of the projectile with the inside of the gun barrel. Reference to the motion of bullets for our present purpose is directed toward the motion of elongated projectiles.

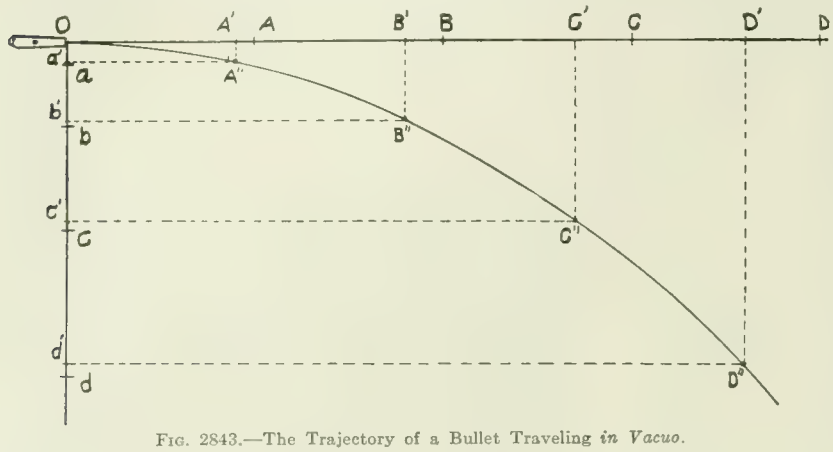


Fig. 2843.—The Trajectory of a Bullet Traveling *in Vacuo*.

Motion of Translation.—As a projectile leaves the gun it is acted upon by three forces: the force of the explosion which propels the projectile forward, the retarding force of atmospheric air, and the force of gravity.

The Forces of Explosion, Air Resistance, and Gravity.—The force of explosion is imparted to the bullet by the liberation of the powder gases. Modern smokeless powder leaves but little residue in the gun; the powder is all converted into gases which are at a high temperature and, as these expanding gases are confined in a small space they exert great pressure on the walls of the gun and base of the projectile. The latter leaves the gun with a certain muzzle velocity which is known as the initial velocity. The powder gases cease to act on the projectile as it leaves the muzzle and it moves forward with a rate of speed that is influenced by air resistance and gravity; otherwise, it would continue to travel in space at a constant velocity. As we have stated the projectile is constantly acted upon by the retarding effects of air resistance and gravity, until it is finally attracted to the earth by the latter.

Motion of Rotation.—To keep the oblong projectile point forward in its line of flight it is given a motion of rotation coincident with its long axis. This motion of rotation is conferred on the projectile by the spiral grooves in the bore of the gun. The velocity of rotation depends upon the linear velocity and upon the sharpness of the twist in the rifling. In our present service rifle the twist makes one complete turn in ten inches. The rotation imparted by the rifling keeps the bullet point on and prevents it from tipping, but it also causes the bullet to deviate to the right or left, depending on the direction of the twist. This deviation in elongated bullets is called the drift.

Trajectory.—The curve which is described by the center of gravity of a bullet is known as its path or trajectory. A bullet travelling *in vacuo* (Fig. 2843), descending to earth under the influence of gravity would describe a trajectory in the shape of a parabola. Fig. 2844 shows how much the trajectories of our military rifle bullets are deformed by air resistance, and Fig. 2845 shows the influence of air resistance on lessening the danger space. The effectiveness of rifles in war is increased by flattening the trajectory and thereby increasing the danger space. The curvature of the trajectory is primarily due to gravity. A bullet in flight is subjected to the law of falling bodies, that is, the bullet will have fallen 16.08 feet below the horizontal plane through the muzzle of the gun in the first second; 64.32 feet at the end of two seconds and for succeeding seconds its rate of fall will be equal to the square of the times multiplied by 16.08 feet. In order therefore to flatten the trajectory of their bullets and thereby to increase the danger space, gun-makers seek to make bullets travel at great velocities in order to cover as much space as possible during the descent of the projectile to earth.

Sectional Density and Form.—At the same time that gun-makers have improved the interior ballistics of their weapons in order to obtain a high velocity, they have also sought to maintain that velocity as much as possible by reducing the air resistance. They have done this by maintaining the sectional density of the bullet at the same time that they have decreased its diameter. The form of a bullet plays a marked rôle in reducing air resistance. The resistance offered by the air to a spherical-headed bullet is a fourth greater than that offered to the ogival-headed bullet which we have recently discarded. With a view to diminish the air resistance still more we have now adopted the pointed bullet

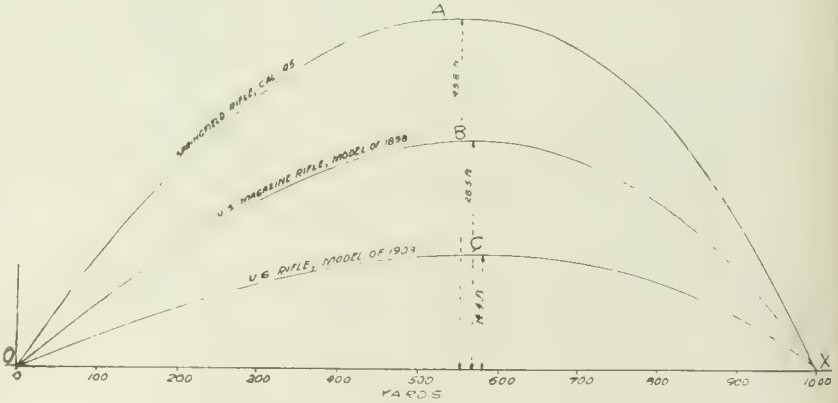


Fig. 2844.—Deformation of the Trajectory of a Rifle Bullet by Air Resistance.

In addition to pointing the bullet experiments are now being conducted with rifle bullets to ascertain the effectiveness of a rear ogive with a view to still further reduce retardation due to air resistance.

Energy.—The energy which a bullet exerts on impact against a resistant structure is of special interest to surgeons. It is the energy of bullets that enables them to break bones and destroy tissues. Formerly the

gun-maker sought to increase the energy of projectiles by increasing the mass. To-day, on account of our superior knowledge in the manufacture of firearms, and the use of the high explosives, gases no longer escape by the side of the bullet, the whole of the expansive force of the high explosives is exerted on the chamber of the gun and the base of the bullet. As a consequence the bullet is shot forth at increased velocity and its energy is correspondingly greater. The gun-makers have found that doubling the velocity increases the energy of projectiles four-fold, and the scheme of attempting to add to the energy of a given bullet by adding to its mass is no longer employed since doubling the mass only doubles the energy.

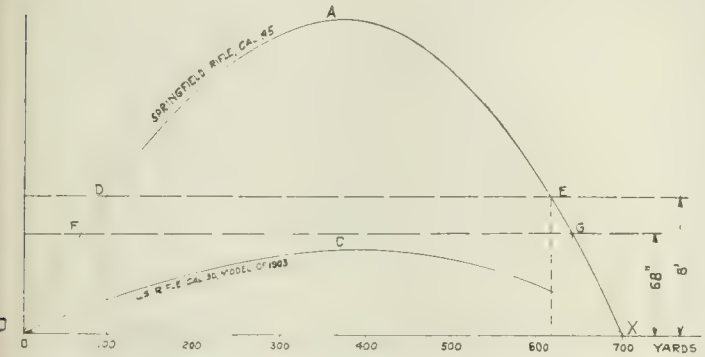


FIG. 2845.—The Influence of Air Resistance in Lessening the Danger Space.

liability to infection; and for these reasons they are much more amenable to modern scientific methods of treatment.

Wounds by the *old round balls* which measured from 0.63 to 0.75 calibers, exhibited destruction of tissue in proportion to their calibers. The velocity of projectiles was then comparatively low and the projectiles were prone to lodge, a complication which added to the dangers of infection. The entrance wound was correspondingly large and usually round, surrounded by an area of ecchymosis. The walls of the channel made by the bullet in soft tissues were more or less devitalized and filled with hematoma which served to augment the tendency to the prevalent infections of that day. The exit wound in the skin was larger than the wound of entrance; it was not usually round, but triangular, oval, or star-shaped with everted edges.

The effects of these bullets on *osseous tissues* were first a flattening of the soft lead of which they were composed, and then lodgment of the missile. When traveling at their maximum velocity of about 600 f.s. these large bullets caused extensive damage, though not so extensive as that noticed by the conoidal bullets of a later day. The area of fracture was not so widely distributed, but the detached spicula of bone which were forced in the surrounding tissues added to the dangers of infection.

Wounds by the *cylindroconoidal bullets* caused extensive destruction of tissue from the beginning of

TABLE I.—PATTERNS AND PERIODS IN THE EVOLUTION OF SMALL ARMS.

Designation	Caliber and shape of bullet	Metal	Weight bullet, grains	Powder, grains	Initial velocity, ft. sec.	Effective range, yards	Outlines of projectiles	
Smooth-bore, flint-lock musket, 1700	.7559 to .6929 spherical	Soft lead	580 to 484	354 to 277 loose black	590 to 754	164 to 328		1. Smooth-bore muzzle-loaders of this type were used with the flint-lock from about 1700 to 1840 and with the percussion-cap until rendered obsolete by the introduction of muzzle-loading rifles and elongated bullets in the Crimean War, 1854 and 1856.
Minnie-rifle, 1851.....	.6929 to .6771 conical	Soft lead	686 to 555	151 black	931 to 1017	874 to 1093		2. First used in percussion-cap muzzle-loading rifles which appeared in Crimean War; used also in Italian War (1859), the American Civil War (1861-65) and by the Danish and Austrian troops in war with Prussia, 1864-66.
Enfield-rifle...	.5708 cylindro conical	Soft lead	535	151 black	1017	874 to 3112		
Needle-gun, 1864 and 1867	.5354 oval .4842 oval	Soft lead	483 and 331	74 black	984 to 1148	1093 to 1640		3. Breech-loading rifles first appeared in the Needle-gun of the Prussians in the wars of 1864–1866. Used in Franco-German war, 1870, 71 under the name of Chassepot; by the Turks as the Peabody-Martini in the Russo-Turkish war of 1877–78; under the name of the Gras, in the Crimean war of 1891, and by the United States under the name of the Springfield rifle in all of its Indian wars from 1873 to 1893.
Chassepot, 1866.....	.4645 cylindro conical	Soft lead	385	86 black	1377	1640 to 2187		
Gras of the French, Old Mauser of Germans, etc., Springfield of U. S., 1873.	.4291 cylindro conical	Compressed lead	480 to 385	70 to 81 black	1301 to 1410	1460 to 2734		
New Mauser of Germans, Lebel of the French, Krag-Jergenson by U. S., etc., 1886–1893.	.3227 cylindro ogival	Hard lead core and cupro-nickel case	220 to 233	43 smokeless	2066	3280 to 4374		4. Breech-loading magazine rifles with reduced calibers, steel jacketed, ogival headed bullets, with smokeless powder, appeared in 1886 and later adopted by all nations. Used in South American revolutions about 1891 under name of Mannlicher, and later in the Spanish-American War 1898-Krag-Jergenson and Spanish Mauser.
The reduced caliber rifles of England, Germany, etc., U. S. rifle (New Springfield) Model 1903	.3083 pointed	Core of lead, cupro-nickel	150	47 to 50 pyro-cellulose	2700	5465		5. Breech-loading magazine rifles of reduced caliber the same as No. 4 except that the bullet is pointed in shape and known as the Bullet S. Now adopted by Germany, England and United States. First used in the Turko-Balkan War in the German Mauser, 1912-13.

LESIONS CAUSED BY PROJECTILES.—*Wounds by Projectiles from Hand-weapons.*—There have been radical changes in the character and treatment of gunshot wounds in recent years. Gunshot wounds by hand weapons like the military rifle are not comparable to those of twenty-five years ago, in severity or their use, so much so, that accusations and recriminations of the use of explosive bullets were often made by combatants in the wars of that period. This notion was brought about by the great destruction wrought by the impact of these bullets against hard bone, an appearance which simulated the pressure of

an expanding force from within. (See Table I, p. 797, Evolution of Small Arms.) As may be surmised from this table, the aim of the ballistician was directed toward increasing the velocity of the projectiles. This was done by securing a perfect fit of the projectile in the barrel to prevent the escape of the expanding

Fig. 2846.—Lodged Conoidal Ball, Radiating Fracture. No. 3175 A. M. Museum. Specimen from Civil War, 1861–65.

gases by the side of the bullet. As a consequence the shock of recoil was increased to such an extent that the caliber and weight of the projectile were reduced, and to lessen the recoil still more, the amount of propellant was also reduced. These changes had a corresponding effect on the characteristics of gunshot wounds. The wounds of entrance and exit were smaller and the amount of devitalized tissue, when soft parts alone were involved was less.

Fig. 2847.—Lesion by Conoidal Ball. From amputated limb. No. 3245 A. M. Museum. Specimen from Civil War, 1861–65.

Bone Injuries by Cylindroconoidal Bullets.—When a cylindroconoidal projectile of about 0.45 caliber happened to collide with a resistant bone like the shaft of the femur at proximal ranges not exceeding 350 yards, the pathological lesion inflicted partook of the nature of a wound with explosive effects. In such an injury the wound of entrance presented no special features from that of a wound of soft parts alone, except in instances where bone lay immediately beneath the point of entrance as the anterior surface of the tibia or the clavicle, in which case the entrance wound was apt to exhibit bony sand. The point of impact against the resistant bone showed loss of substance, from minute fragmentation. Larger spicula of bone were driven in the flesh about the area of fracture in all directions. There was extensive destruction of soft parts complicated by hematomata. Fissures were present in the shaft above and below the fracture. The bullet which was composed of lead, was flattened, fragmented, and lodged partly or entirely in the majority of instances. The wound of exit was very large, irregular in shape, measuring in some cases three and four inches in diameter. The lesion of the tissues from the area of fracture to the exit wound in the skin was funnel shaped with the apex of the funnel pointing to the foyer of fracture, while the base was represented by the exit wound. The foregoing marked

A B

Fig. 2848.—Photograph of Perforation in Head of Tibia by .30 cal. German Silver-jacketed Bullet, Shot out of the Experimental Springfield Rifle, into a Cadaver at a Simulated Range of 1200 Yards by the Author. Bullet used is undeformed and shows to left of specimen. (A) Orifice of entrance; (B) orifice of exit. Army Med. School collection.

the typical conditions in a fracture known as "explosive effects." If the conoidal bullet happened to traverse the epiphyseal end of a bone, there was not so much tendency to fissuring of bone or detachment of large fragments. The bullet was apt to gutter the bone or make a perforation in the osseous tissues, depending on the angle of impact against the surface. Guttering and perforation of the epiphyses were more frequently seen at the mid-ranges from 500 to 1,500 yards. The differences in the lesions of the diaphyses and epiphyses were wholly due to the degree of resistance in the two structures. The more spongy bone having less resistance, and being in the nature of soft tissues, the lesion was always less.

Injuries from Steel-clad Bullets.—Our earlier knowledge of the effects of reduced caliber bullets came to us as a result of experiments which were conducted by experimenters on behalf of the great governments during the decade 1882–92 at a time when there were no wars to test the value of the changing armaments in battle. The limits of this article do not permit

extended reference to this important subject but we may state here that the results of the experimenters were later fully confirmed by observations in the wars which have since taken place.

In the Spanish-American War, at the battle of Santiago, we had the first opportunity of observing the effects of steel-clad bullets of reduced caliber on

Fig. 2849.—Front View. Radiograph in case of W. K. showing perforation of upper end of tibia. Wounded June 25, 1899, by a Krag-Jorgensen bullet at a distance of 10 feet. Radiograph taken 30 months after injury. Remote effects: slight weakness and pain at site of wound. Good motion in joint. U. S. Soldiers' Home collection.

the living. Our army carried the 0.30 caliber Krag-Jorgensen rifle, while the Spaniards used the Spanish Mauser of 0.27.6 caliber. The ballistic value of the two guns was very much alike and the wounds noticed on both sides were very similar. In the Anglo-Boer War, the Boers carried the Spanish Mauser whose features are very much the same as the Mauser of the Spaniards already referred to. Their forces were also provided with some Krag-Jorgensen rifles and a few Martini-Henry's but the bulk of the wounds according to British returns were inflicted by the Spanish Mauser. The British troops were provided with their 0.303 caliber Lee-Enfield whose ballistics correspond to those of the Krag-Jorgensen. In the Russo-Japanese war the Russians carried the 0.30 caliber Mossin-Nagant, a gun very much like the Krag-Jorgensen in ballistic value. The Japanese army was provided with two rifles very similar in the wounds which they inflicted. The first line of their army carried the Arisaka rifle of 0.25.6 caliber which has a muzzle velocity of 2,390 f.s.; the weight of projectile, 162 grains. The rest of the army carried a gun which as to caliber, velocity, and penetration corresponded to our Krag-Jorgensen, and the Lee-Speed of the British ten years ago. In a general way it may be stated that the wars just mentioned were fought with the use of hand rifles that were quite similar and the projectiles from these guns inflicted wounds having great similarity. On the other hand the last great war, viz., the Turko-Balkan War of 1912–13 showed a marked departure in the use of armaments, and the wounds received will be specially referred to later. The troops of the Balkan States were armed with the Mannlicher rifle of reduced caliber which about corresponds to the Krag-Jorgensen gun with which we fought the Spanish-American War. Their army was well provided with three-inch field guns using shrapnel. The gunners were well drilled in the system of indirect fire, and the large number of casualties from this arm has formed a subject for special comment by military critics and surgeons generally. The Turkish army was provided with the German Mauser rifle which uses the pointed bullet so recently adopted by Germany, England, and the United States. The effects of this bullet were tested on the living for the first time in this war. The lesions which it produces at times are quite a departure from those noticed hitherto as a result of injuries by steel-clad reduced caliber bullets.

Concerning the effects of the ogival headed bullets of reduced caliber in the Spanish-American, Anglo-Boer, and Russo-Japanese Wars the characteristic lesions are quite similar and they may be summarized as follows: The wound of entrance in the proximal ranges before the bullet has become steadied in flight, is at times larger than one finds it in the battle and remote ranges. The outline of the entrance wound depends upon the angle of impact with the surface—it is round if the bullet impinges perpendicularly, and oval if it strikes at a tangent. In skin overlying bone, over the tibia, sacrum, etc., the wound appears larger than the diameter of the bullet, while in skin with underlying areolar tissue like the scrotum, the wound of entrance appears smaller than the bullet, it is irregular in shape, but more often marked by a linear slit. When irregular, the entrance wounds suggest the passage of a ricochet bullet through the skin. The edges of the entrance wound are usually inverted or depressed at first and they are covered with dirt from the gases of the propellant and dirt from other sources. The friction of the projectile in passing through the skin leaves a flesh-colored ring composed of the cuticle deprived of its epithelium, which appears under the dirt referred to. The denuded cuticle soon dries and its pink coat turns to brown. The ecchymosis so common around the wound of entrance from the older and larger bullets, is not so marked after wounds of reduced caliber.

The exit wound is more variable in shape and larger as a rule than the entrance wound. The wounds of entrance and exit in the proximal ranges when a regular impact has been made in soft tissues, bear great similarity and it is difficult to distinguish the one from

Fig. 2850.—Skiagram Showing Side View of Fig. 2849.

the other, a fact which should be remembered on account of its medicolegal importance. As already stated the entrance wound may show inverted edges, while in the exit wound the edges are usually everted. In soft parts alone the exit wound is round. It is lacerated when the projectile passes through loose skin at moderate velocity, and slit like if it makes its exit at the higher velocities. Exit wounds showing the great-

est size and irregularity are seen after compact bone injuries when the velocity of the bullet is at its maximum. The exit wound in such cases may be several inches in diameter, presenting all of the characteristics of a wound with explosive effects (Fig. 2851).

Reduced caliber bullets are seldom deflected, they travel in a straight line from the point of entrance to their place of lodgment or wound of exit. The channel through the soft parts is incised, like the channel of a wound by a knife. It has but few of the lacerated and contused appearances seen in wounds caused by larger bullets possessed with lower velocities.

Fig. 2851.—Exit Wound Showing Explosive Effects on Bone by Japanese Rifle at Short Range. Russo-Japanese War. (Lynch.)

The tissues surrounding the bullet's channel show the presence of hemorrhage, slight contusion, and engorged vessels. The track itself contains hematomata. Perforations in tendons and the more resistant fasciæ are slit like in shape, but a tendon may be cut across when the bullet makes an impact side on. On account of its smaller frontage the new military rifle bullet carries less foreign matter such as shreds of clothing, part of the equipment of soldiers in wounds, etc., than the old-time larger projectiles.

Injury to Blood-vessels.—From the incised character of the lesion in soft parts injuries to blood-vessels are more common in war wounds now than formerly. These small steel-clad projectiles, cut small vessels across and they scoop larger vessels on the side, like a knife. The largest vessels are perforated at times leaving an orifice of entrance and exit with a band on each side. The clean-cut character of the wound in the coats of the vessels favors hemorrhage in the tissues, causing traumatic aneurysms; and when the hemorrhage occurs in the body cavities death ensues more promptly than heretofore. The narrow track of the bullet in muscle and soft parts is readily obstructed by a change in the position of adjoining layers of muscle and fascia, so that a vessel in a limb is not attended with alarming external primary hemorrhage as often as formerly.

Injury to Bone.—In war twenty-two per cent. of all gunshot wounds were formerly complicated with bone injury. The change in the armament from the larger to smaller calibers, in so far as recent wars are concerned, has not altered the above noted percentage.

Injury to the *diaphyses* of long bones by the jacketed bullet is marked by extensive fragmentation in the proximal ranges. Within the first three hundred yards, the bone lesion is attended with all the features of explosive effects in wounds such as those referred to by the larger conoidal lead bullets. In the mid-ranges the tendency in bone lesion is toward perforations, incomplete, and subperiosteal fractures. The fissures are longer and the bone fragments when actual fracture takes place are not so badly displaced as they are in the near-by ranges. In remote ranges the diaphyses again show decided fracture with more marked displacement of fragments, a fact which has been noted by all experimenters and which is ascribed to irregular impact of the bullet after it loses its balance in the latter end of its trajectory. The observations of the experimenters on this point have been repeatedly confirmed by surgeons in recent wars. It has again and again been noted that a bone lesion inflicted at 2,000 yards is decidedly more fragmented than one which is received at 1,000 to 1,200 yards.

Injury to *epiphyseal ends* of bones is marked by clean-cut perforations at all ranges when the bullet makes a regular impact. The joint ends of bone are made up of soft cancellous tissue and unlike the compact substance of the diaphyses they offer but little resistance, hence the limited area of destruction at the point of impact. This characteristic effect of the new military rifle bullet on joints has contributed materially to the number of humane wounds in recent wars.

Injuries to the Head.—Anteroposterior, transverse, and oblique shots through the cranium at proximal ranges are marked by decided explosive effects. In such injuries one finds numerous fissures radiating toward each other from the points of entrance and exit in the vault, while fractures extending through the temporal, sphenoid, and other bones at the base of the skull are not infrequent. In suicides who hold the muzzle of the gun at contact the skull-cap and overlying skin are often blown entirely away. At the battle ranges from 800 to 1,500 yards the destructive effects are not so great. At these ranges lesions, obliquely and transversely disposed, when properly treated have shown marked tendency to recovery in recent wars.

Effects of the Pointed or Spitz Bullet of the Germans.—The pointed bullet referred to was adopted by our army in 1906, and it is now used in the military rifles of England and Germany. It was first used in war

by the Turkish army in the recent Turko-Balkan War. (Fig. 2852). The U. S. Army bullet is 1.08 inches in length; 0.3083 inch in diameter; weight 150 grains; the jacket is composed of cupro-nickel steel. Its velocity of translation is 2700 f.s. at the muzzle and the velocity of rotation is 3240 turns per second as it leaves the weapon. The point-blank range while firing standing is 718.6 yards. Such a flat trajectory makes the bullet very popular with military men.

Fig. 2852.—Photograph Showing Turkish Cartridge and Pointed Bullet Used in the Turko-Balkan War.

The bullet is short, and the point is so tapering that its center of gravity is located near its base. Its stability is very much impaired thereby. The least resistance upsets it and in turning at great velocity (Fig. 2853), the wounds it inflicts are very much lacerated and otherwise attended with destructive effects which are not unlike the wounds inflicted by Dum-Dum bullets. For this reason, the new pointed bullet is a great disappointment to military surgeons. In experiments which we conducted two years ago, we found the resistance encountered in the hip-joint, chest and abdomen of cadavers sufficient to cause the bullet to turn and the resulting wounds were like those of an expanding or metal-patch bullet (Fig. 2854).

Colonel Roosevelt, in his "African Game Trails," refers to the wounds of the pointed bullet as having a slashing effect against large game. At 280 and again at 180 yards he brought down two bulls each with one shot, the bullet making "a terrific rending compared with the heavier ordinary shaped bullet of the same composition." At 350 yards he killed a hyena. Its throat was cut, the sharp-pointed bullet made a slashing wound.

Fig. 2853.—Experimental Shot in Cadaver. Keyholing of pointed bullet in blotting paper behind target after going through hip-joint at a simulated range of 100 yards.

Among the Bulgarian casualties in the Turko-Balkan War of 1912–13, the ratio of killed to wounded was 1 to 2.4, a much higher ratio than has been noted in any of the recent wars and the surgeons believe that the mor-

Fig. 2854.—Explosive Effects in Right Thigh of a Cadaver Due to Pointed Bullet Shot out of U. S. Magazine Rifle at Simulated Range of 100 Yards. Entrance wound round, size of bullet. Exit wound 6 inches long, by 3 inches wide; opening large enough to admit fist. Bullet hit femur in middle third causing extensive fragmentation and it then struck head of barrel behind the target, side on. Army Medical School collection.

Fig. 2855.—Skiagram of Fractured Humerus with Explosive Effects by Turkish Bullet at Battle of Lulu Bergas, 400 Meter Range.

tality list was materially increased by the use of the spitz-bullet used by the Turks.

Those with body wounds inflicted by this bullet seldom lived to reach hospital care. Abdominal wounds were very fatal and chest wounds ending in recovery were very prone to complications like hemothorax, pleuritis, pneumonia, etc. (Fig. 2855.) The percentage of lodged balls was large, and this is what we might expect from the poor balance of the bullet as already noted.

Fig. 2856.—Skiagram Showing Oblique Fracture of the Tibia by Ricochet Turkish Pointed Bullet.

War wounds by the military rifle are destined to be much more grave in the future. Body wounds will be attended with greater fatality; bone injuries will be more extensive, and the humane features of reduced caliber wounds so universally noted in others of the recent wars in tissues like the lungs and epiphyseal ends of bones will be less frequently seen.

The Stopping Power or Shock Effects of Rifles, Pistols and Revolvers.—The stopping power of projectiles from firearms is of material importance to hunters after large game, in war against savage tribes, in warfare against horses in a cavalry charge, and between enemies in personal combat. Under the circumstances mentioned when firearms are used the weapon that stops an enemy by the shock of impact most effectually, lends a sense of security to the party who is doing the shooting and such a weapon is considered far more valuable on account of its stopping power.

The stopping power of the reduced caliber rifles of the present day has been sufficiently tested in war in the last few years to demonstrate that it is sufficiently effective for all the purposes of civilized warfare. When a soldier is hit in battle by the new bullet, he generally falls back. On the other hand it is of doubtful value on horses in a cavalry charge, and it is notably so against fanatics and savage tribes. Against these the only recourse is to file the nose of the steel jackets to invite deformation on impact against structures having sufficient resistance to break the bullet up. When this occurs the destructive effects are very much increased, and the reduced caliber jacketed bullets are as effective as the larger lead bullets have shown themselves to be.

The stopping power of revolvers carrying lead bullets like our 0.38 Colt's revolver of a few years ago, was often questioned in encounters against fanatics, especially during the Philippine Insurrection. Fig. 2858 shows how signally a number of body wounds from this weapon can fail entirely in stopping a determined enemy. Instances of failure such as is cited in this case made the stopping power of our revolver very questionable, and for this reason, the War Department

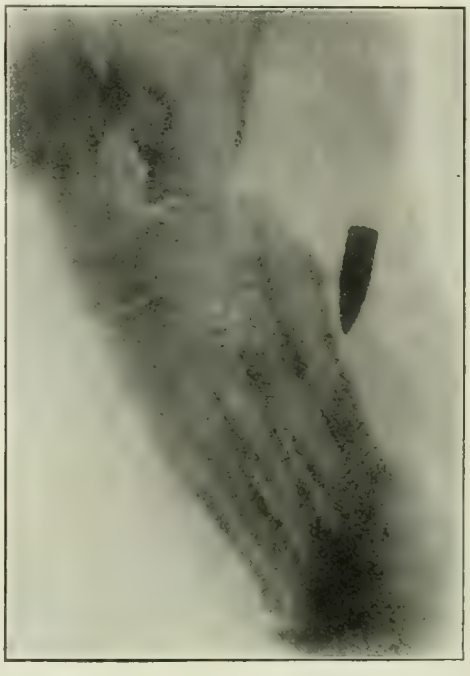


Fig. 2857.—Skiagram Showing a Lodged Turkish Rifle Bullet.

recently constituted a board to investigate the shock effects of various pistols and revolvers for the purpose of determining upon a weapon that should have the stopping power and shock effects at short ranges necessary for a pistol in the military service. The board was composed of Col. John T. Thompson of the Ordnance Department and the writer. The board was furnished a number of pistols and revolvers with certain ammunitions as shown in Table II. The table shows that the extreme range in calibers was between 0.476 inch and 0.3012 inch. To increase destructive effects and to add to the stopping power, soft-nose, and metal-patch bullets were used. In the full jacketed bullets, destructive effects were magnified by filing the nose of the steel envelope enough to expose the lead core.

The form of bullets which adds to their destructive effects, such as bullets with truncated cone, spherical segment, blunt-point, hole-in-point, cupped nose, and one bullet with a hole-in-point filled by a copper shell primed and charged (explosive bullet) were used.

The extreme variation in the weight of projectiles was between 92.6 grains and 288.1 grains.

The lowest initial velocity among the projectiles was 700 f.s. and the highest was 1420 f.s.

The lowest muzzle energy was 191 foot-pounds,

FIG. 2858. -Antonio Caspi a Prisoner on the Island of Samar, P. I. Attempted to escape Oct. 26, 1905. He was shot four times at close range in a hand-to-hand encounter by a .38 cal. Colt's revolver loaded with U. S. Army regulation ammunition. He was finally stunned by a blow on the forehead from the butt-end of a Springfield carbine. 1. Bullet entered chest near right nipple, passed upward, backward and outward, perforated lung, and escaped through back passing through edge of right scapula. 2. Bullet entered chest near left nipple, passed upward, backward and inward, perforated lung and lodged in back in subcutaneous tissues. 3. Bullet entered chest near left shoulder, passed downward and backward, perforated lung and lodged in back. 4. Bullet entered palm of left hand and passed through subcutaneous tissues and escaped through wound on anterior surface of forearm. Treated at military hospital, Borongan, Samar. Turned over to civil authorities cured, Nov. 23, 1905. Reported by L. P. Lewald, 1st Lieut. Medical Corps, U. S Army.

TABLE II.—PISTOLS AND REVOLVERS WITH VARIOUS SHAPES OF BULLETS

Make	Model	Caliber	Shots in magazine or cyl.	Powder charge			Bullet			Velocity f s at			Energy ft-lb
				Weight gr	Kind		Weight gr	Kind	Shape of point	Muzzle	37 yd	75 yd	Muzzle
1. Luger Automatic Pistol.	Medium barrel	3012	8	6 2	Smokeless		92 6	Jacketed	Truncated cone	1420	1258	1133	415
2. Luger Automatic Pistol.	Short barrel	3543	8	5 2	Smokeless		123 5	Jacketed	Truncated cone	1048	985	930	301
3. Colt's Revolver...	Army, 1903	38	6	3 3	Bull's eye		148 0	Lead	Sph seg	763	727	690	191
4. Colt's Automatic Pistol.	Military 1902	38	8	6.6	Smokeless		130 0	Jacketed	Sph. seg.	1107	1022	953	354
5. Colt's Automatic Pistol.	Military 1902	38	8	6 5	Smokeless		120 0	Soft nose	Sph seg	1048	980	920	293
6. Colt's Revolver...	New Service	45	6	4.8	Bull's eye		250.0	Lead	Blunt point	720	692	668	288
7. Colt's Revolver..	New Service	45	6	4 8	Bull's eye		220 0	Lead	Hole in point	700	691	683	239
8. Colt's Revolver...	New Service	455	6	6 4	Cordite		218 5	Soft lead	Cupped	801	701	616	288
9. Colt's Revolver..	New Service	476	6	18 0	Black		288 1	Lead	Sph seg	729	686	646	340
10. Colt's Revolver.	New Service	476	6	18 0	Black		288 1	Lead, explosive	Sph. seg.	729	686	646	340

and the highest was 415 foot-pounds. The weapons were selected for their value in ballistic elements and not for a test of their mechanism.

The following ranges were selected:

1. Extreme range, seventy-five yards.
2. Medium range, thirty-seven and one-half yards.
3. Short or close range, near the muzzle. Simulated velocities were used for the first two ranges.

In all of its experiments the board fired into ten cadavers, sixteen beeves, and two horses.

In the case of cadavers the degree of shock effects was estimated by the amount of oscillation which was noted in a limb from the impact of a bullet when the body was suspended by the neck. The amount of shock effects as measured by this standard was always proportional to (1) the sectional area of the bullet, (2) the resistance on impact, and (3) the amount of tissue destroyed.

The diaphyses of the long bones offered the greatest resistance and at the same time they exhibited the greatest amount of destruction, and the destruction in the hard bone was always greater with the use of the larger calibers.

The shock effects on living animals had to be determined by the behavior of projectiles on (1) vital parts, (2) non-vital parts, (3) the anatomy necessary to locomotion or parts essential to activity.

All shots against vital parts, naturally showed prompt and complete stopping power.

For shots in non-vital parts like the lungs, liver, intestines, etc., exclusive of large vessels, the stopping power increased with the sectional area of the projectile. It was notably less with the smaller projectiles notwithstanding their superior energy.

Fig. 2859.—Fracture of Humerus by Colt's New Service Revolver .45 cal. Bullet with Blunt Point, Close Range. Army Medical School collection.

The stopping power of bullets was considered positive in fractures of the long bones concerned in locomotion or parts essential to activity. In accordance with this standard all the bullets submitted for trial possessed sufficient stopping power. The stopping power of the larger calibers was considered positive in gunshots of the epiphyseal ends of bones entering into the formation of the ankle, knee, hip, and shoulder, and doubtful when these structures were traversed by the small 0.3012 inch jacketed bullet of the Luger pistol.

Contrary to a popular notion, metal-patch, soft nose, and enveloped projectiles with marred jackets failed to show superior destructive effects in soft parts or the epiphyseal ends of bones. These structures did not offer sufficient resistance to invite deformation and the lesions were quite similar to those inflicted by the full jacketed bullets.

Fig. 2860.—Fracture of Femur; Colt's New Service Revolver .45 cal. Carrying a Bullet with Hole in Point, Close Range. Army Medical School collection.

In some quick firing experiments on beeves it was found that the small caliber projectiles of the 7.65 millimeters Luger failed to bring the animals to the ground until as many as ten shots were delivered in the chest or abdomen away from the spine and large vessels. Similar experiments with the 0.47.6, 0.45.5 and 0.45 caliber Colts new service revolvers brought the animals to the ground promptly in from three to five shots. All of the bullets in the quick firing experiments lodged, so that every particle of energy was delivered and dissipated in the body. It was evident therefore that the energy of a bullet is not so much concerned in producing shock effects, as is its sectional area. This failure of the smaller caliber automatic pistols set at rest the claims of the makers that the superior energy and velocity of their weapons was a controlling factor in stopping power. It became evident from these quick firing experiments that a bullet which possesses the stopping power and shock effects at short ranges necessary for a military pistol or revolver should be a caliber not less than 0.45 inch in diameter.

Aside from the value of the experiments as they relate to stopping power, there were features in the lesions produced by the different bullets on bone especially that will interest both the civilian and military surgeon. To the latter pistol bullet wounds composed of lead are a thing of the past since all military nations have adopted automatic pistols which can carry only steel-clad bullets.

To the civilian practitioner the lesions will be of like interest since the automatic weapons are finding favor more and more in civil communities, and the wounds which general practitioners deal with in civil hospitals will soon be almost exclusively from steel-

clad bullets. We herewith give illustrations from skiagrams made at the time of the experiments referred to, which, with the captions, show at a glance the differences between the lesions of lead and jacketed projectiles (Figs. 2859–2862).

In the foregoing pages we have had frequent occasion to refer to the subject of *explosive effects* in gunshot wounds. The term so employed is descriptive of extreme traumata that one occasionally sees in wounds by high velocity projectiles of the military

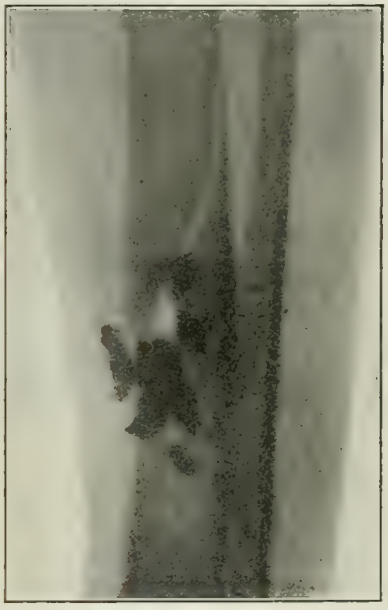


Fig. 2861.—Fracture of Tibia from Man-stopper Bullet Fired from Colt's Revolver New Service Cal., .455, Velocity 704 f.s Bullet fragmented and lodged just under skin. Army Medical School collection.

rifle in the proximal ranges. The extreme lesions referred to are more often seen in wounds against resistant osseous structures although the organs containing fluid or semi-fluid masses like the stomach, intestines and urinary bladder may exhibit similar lesions. In a gunshot wound showing explosive effects when bone is implicated, the wound of entrance presents no special features except that in a certain proportion of cases it may contain bony sand. The resistant bone at the point of impact is finely comminuted, and small particles of osseous tissue will appear driven in all directions, forward, laterally, and backward in the soft parts. The latter will be pulpified and totally deprived of their vitality for some distance about the bullet's channel. The exit wound will be very large, as much as 9 to 12 inches in area. Torn muscles, tendons, lacerated nerves, mingled with pieces of bone give the appearance of an explosion having occurred from within, and such lesions are not unlike the lesions caused by explosive bullets, bullets that are charged with gunpowder and provided with a cap on their point to cause actual explosion on impact, hence the term "explosive effects" in these wounds.

Many writers have advanced theories to explain these distinctive effects by the high-power rifles; they have been ascribed in turn to (*a*) compressed air which was said to be massed on the nose of the projectile, as it was forced onward; (*b*) hydraulic pressure; (*c*) the rotation of the oblong projectiles; (*d*) deformation of the bullet, and (*e*) heating of the bullet. It may be proper to admit that the agencies under (*b*), (*c*), and (*d*) have in a minor degree some contributing influence in bringing about part of the destructive effects, but explosive effects such as we have described, have been explained otherwise.

The True Cause of Explosive Effects.—Examination of the area of fracture and the funnel-shaped channel of a gunshot wound with explosive effects shows the presence of spicula of bone, and when the bullet has disintegrated, metallic particles will be found to have been forced into the tissues in all directions. Each particle of bone and metal appears to have been animated by a force which caused it to act as a secondary projectile. These secondary projectiles have in reality been impressed by part of the energy which the bullet possessed on impact, and the amount of energy in each particle is proportional to the amount of remaining velocity which the bullet possessed when colliding with the bone. When the projectile collides against the wall of a cavity containing fluid, the latter is dispersed and part of the energy of the bullet is transferred to particles of the fluid contents and they in turn are propelled forth to act as secondary projectiles. The true cause of explosive effects is the transfer of the bullet's energy to particles of its own composition when it disintegrates, as well as to spicula of bone, particles of fluid, or

Fig. 2862.—Fracture of Femur by Colt's New Service Revolver, Carrying Man-stopper Bullet, Caliber .455 with Simulated Velocity at 37½ Yards. Note butterfly character of fracture. Army Medical School collection.

soft tissues. The degree of destruction is measured by the amount of energy originally possessed by the bullet, and the amount of the latter corresponds to the velocity of the projectile on impact. Sectional area and deformation of the bullet favor destruction of tissue, but they are not essential, because we know that the lesions from small jacketed bullets often exhibit all the characteristics of wounds with explosive effects when the bullet itself has not been deformed.

Wounds of the Artillery Arm.—This class of wounds is inflicted by shells, shell fragments, and shrapnel.

Shell wounds more often result from shell fragments. They are lacerated, contused and correspond to the size of the missile. Since the missiles are impressed by low velocity, lodgment of metallic fragments is very frequent. When the whole shell strikes the body it carries everything before it, and when it makes a central impact it leaves a hole in the body corresponding to its caliber, and adjoining viscera are dislodged and scattered. When a limb has been carried away the stump presents a level surface with tissues very much contused. The skin and muscles are devoid of the contractility that is normally present in amputated limbs. Injuries by the whole shell while traveling at lower velocity are marked by more laceration of the skin and other soft parts, the bone exhibits larger spicula, and the fissures in the shaft remaining, are longer. There is more extravasated blood and greater contusion. Trauma from spent shells may not exhibit external evidence of injury although disorganized tissues, lacerations, contusions and crushing of soft parts with or without bone injury are present.

Except in fortified positions and on board ship shell wounds are infrequent in modern wars. In the field nearly all the artillery casualties in recent wars like the Spanish-American, Anglo-Boer, Russo-Japanese, and Turko-Balkan wars were caused by bursting shrapnel. The large majority of the *shell wounds* reported in these wars are erroneously reported as such. The accuracy and effectiveness of field artillery fire with bursting shrapnel marks one of the great advances in the gunnery of the present day, and eighty per cent. of the ammunition of the mobile artillery is composed of shrapnel. Surgeons are wont to class wounds from artillery fire as coming from shells, when in reality, the wounds have been inflicted by shrapnel balls. According to our returns shell wounds in the Spanish-American war formed seven and one-half per cent. of all wounds, but we know that comparatively few shell wounds *per se* occurred. The reporters from all the wars since have had occasion to refer to the same error.

Wind contusion is one of the vagaries of old time writers on gunshot wounds. When shot and shell were extensively used in battle, surgeons often met cases of severe internal injury to viscera and soft parts and fracture of bone with no evidence of injury to the surface. These traumata were erroneously attributed to the rapid displacement of air by a shot passing near the surface, hence the term wind contusion. The more intelligent surgeons learned with time that the injuries included under this designation were in reality due to the result of pressure from the large heavy projectiles of those days, when they were impressed with a slow momentum against a tough elastic skin.

In the Manchurian campaign the Japanese shell was loaded with chimose powder, an explosive which emits poisonous gases on exploding. The force of explosion and the effects of the fumes caused a mental shock and nervous symptoms like neurasthenia or traumatic hysteria. The case of the chimose shell was broken in minute fragments which penetrated the surface like so many grains of sand, and some of the observers believed that the gases absorbed by the cellular tissue produced the nervous symptoms referred to.

Our knowledge of shell wounds and the injurious effects of the discharge of large guns in recent wars, have come to us from the writings of naval surgeons Saneyoshi and Suzuki[1] describe vividly the casualties on board ship from shells and shell fragments, splinters of planks and furniture, pieces of iron, etc., which are mobilized by bursting shells. Casualties also come from exploding magazines which cause burn and irritation to the mucosæ from the fumes of liberated powder gases. Rapid displacement of air in the vicinity of exploding shells and detonating explosives is responsible for many cases of mangling, lacerations, etc.

Among the more common lesions aboard ship during a naval engagement *contusions* are comparatively rare, because the projectiles which are mobilized have a limited range, and their surface being irregular, the injuries they cause usually involve the thickness of the skin enough to inflict abrasions or lacerations at least; *penetrating* wounds result from missiles of low velocity, when lodgment occurs; *perforating* wounds are caused by missiles having sufficient velocity to penetrate and then leave the body; they have a wound of entrance and one of exit. *Lacerated* wounds are of all degrees of severity; they result from wounds by the entire shell or some of its fragments, producing laceration in the soft parts, or severance of a limb, or the entire body may be cut in two, entirely or partially. *Mutilating* wounds occur when the anatomical parts of the body are mangled beyond recognition. *Burn* is the most common of the injuries in modern naval combat; it may arise from the escape of steam when boilers are perforated by projectiles or otherwise destroyed, but it generally arises from the explosion of shells and the ignition of ammunition. *Poisoning from powder gases* which are liberated from the bursting shells of the enemy and the discharge of the batteries on board each ship constitutes one of the chief dangers of naval warfare today. The products of combustion of the high explosions yield CO and NO_2, and as pointed out by Surgeon General Stokes of the U. S. Navy,[3] there will be two types of poisoning, "one resembling illuminating gas poisoning, the other irritative in its effects. Both may vary in degree. In the one group, in mild cases, we find dilatation of the pupil, impaired vision, a fall in blood pressure, a rapid heart action, and possibly some mental confusion." The degree of poisoning will vary from slight degrees to a dosage sufficient to cause unconsciousness and death.

Among the complications *rupture of the membrana tympani* is frequently noted from the reverberations attending the discharge of large cannon and exploding ammunition; *hemorrhage* is not often noted because of the lacerated and other features in shell wounds which stay the flow of blood; *shock* as a result of severe wounds, and a mental shock from proximity to bursting shells is not infrequent; *traumatic delirium* among wounded men in the vicinity of exploding magazines is frequent. Burn nerve exhaustion, insomnia, and pain are also laid down as causes of traumatic delirium.

The severity of naval war wounds by modern armament, and the rapidity with which the casualties occur are well summarized by Mathiolius[4] in his description of the attack of the Japanese war ships against the Russian Cruiser Varyag at the beginning of the Russo-Japanese War. The vessel was placed *hors du combat* in fifty minutes with a casualty list of eighteen per cent. of her effectiveness. There were forty-one killed and sixty-four wounded. Men were entirely mutilated by the large shells; immediate amputation became necessary in a number of cases. One sailor received 160 wounds from the explosion of one shell.

The casualties before Port Arthur from February 9, to October 1, 1904, numbered 2,321 from all causes.[5] The total mortality was 1,022. The severely wounded numbered 556 and the slightly wounded numbered 655. Shell wounds were generally multiple. In thirty-six wounded specially noted there were sixty-two wounds, not counting slight excoriations, etc. The wounds ranged from the size of a pea to trauma sufficient to mutilate a limb.

Wounds by Shrapnel.—Wounds by the modern shrapnel have entirely superseded those from the old

time canister and case shot. The lesions from shrapnel balls are quite similar to those from the ordinary round lead ball of older times. The missile has slow momentum, it often lodges, and all the wounds suppurate. Body wounds are very fatal. Wounds

Fig. 2863.—From Turko-Balkan War 1912–13. Bulgarian artilleryman wounded by a bursting shrapnel at Lule Burgas.

of the lungs that recover are prone to the development of complications like hemothorax, pneumothorax, and empyema. Wounds from part of the casing of the projectile do not differ in character from injuries by shell fragments.

There are but few shrapnel wounds recorded in the Spanish-American, and Anglo-Boer wars, but the field guns were well provided by shrapnel projectiles in the Russo-Japanese and Turko-Balkan wars, and in the latter the ratio of wounds from this source has exceeded that from all former wars. Of 25,000 wounded received in the hospitals at Sophia from the battles near-by the shrapnel wounds noted by our Attache Major P. C. Fauntleroy, Medical Corps, U. S. Army, amounted to thirty-five per cent. of the whole number of wounds. Some observers found the number of shrapnel wounds as high as ninety per cent. of all wounds in the Constantinople hospitals after the retreat from the Tchatalgia lines (Figs. 2863 and 2864).

Wounds from Hand Grenades, Bombs, and Mines.—Hand grenades were used in ancient times in defensive warfare, but they fell into disuse for a long time until again employed first by the Japanese at Port Arthur. The lesions they cause are the same as those inflicted by the detonating high explosives with the addition in some instances of the lodgment of many small metallic particles from the casing or body of the grenade. The wounds are described as difficult to treat. They are all infected and the propellant leaves a yellow color in the wound, and pain is present for some time after the wound has entirely healed (Fig. 2865).

Wounds from bombs and mines do not differ from the lacerations which are caused by the rending effects of the high explosives. The mines which are buried under ground in wooden boxes propel gravel, sand, and splinters of wood into space which cause some of the traumata. Such injuries are prone to the development of virulent infections like malignant edema and tetanus.

Wounds from Pistols and Revolvers.—Wounds from revolvers in present use and those in former times which propelled lead projectiles with low velocities are prone to exhibit lodged missiles. Fracture is not so often noted as it is with the higher velocities from rifles and automatic pistols. When fracture takes place the area of bone lesion is prone to show fissures into the shaft of the long bones and to lodgment of metallic fragments from disintegration of the projectile. Injuries to joint ends of bones are marked by grooves or clean-cut perforations with little or no splintering.

Injury to compact bone from the latest automatic pistols with higher velocity like the Colt's, Luger, and Savage weapons which carry bullets of lead enveloped in a mantle of hard steel, is almost invariably attended with fracture. The area of fracture is more circumscribed about the point of impact, the bullets do not disintegrate, metallic fragments are seldom deposited, and the bullet does not so often lodge. The lesions in the joint ends are less severe. Perforations are clean cut.

Body wounds from automatic pistol bullets are generally more severe and they show a greater amount of laceration and contusion. This is ascribed to the high velocity which is impressed on the short projectile. The subject of the lesions from pistols and revolvers is more extensivelydealt with in the section on the stopping power of pistols and revolvers to which the reader is referred.

Blank Ammunition and Toy-pistol Wounds.—Blank ammunition wounds have been noted a great deal abroad in recent years in army maneuvers. The lesion from such a source at short range is marked by laceration of soft parts and the lodgment of powder grains and wadding. The wounds from toy pistols are very similar. The hematomata, contusion, and laceration afford a favorite pabulum for the development of septic microbes and virulent infections

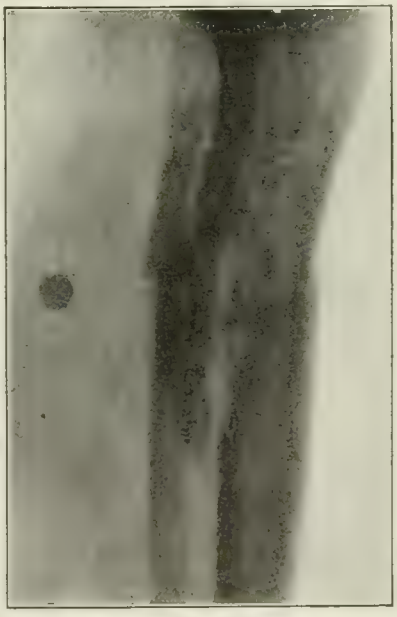


Fig. 2864.—Turko-Balkan War 1912–13. Bulgarian wounded by Turkish shrapnel at Kirk-Kalisse. Fauntleroy collection.

like tetanus are not infrequent. The subject of toy-pistol tetanus is a familiar one to surgeons in the United States where so many cases of tetanus have developed in the wounds which occur during

the celebration of Independence Day, July 4, of each year. The particular source of infection in these cases was the subject of diligent research for years, but the investigators have finally concluded that the bacilli of Nicolaier enter the wounds which are generally inflicted on the hands of children who use these weapons on the street where the droppings from animals contain the necessary germs in abundance.[6]

Fig. 2865.—Wound Produced by Explosion of Hand Grenade, Russo-Japanese War. (Lynch.)

Wounds from Shotguns.—These wounds differ in characteristic features with the distance, size of shot, and the amount of propellant. Close shots show laceration, destruction of tissue, hematomata, fracture of bone, and lodgment of individual pellets. The cone of dispersion of the pellets increases with the distance and beyond the very close ranges the lesion nflicted is that of each individual pellet. The severity of the wound from the latter depends upon the anatomical part involved (Figs. 2867 and 2868).

Wounds from Air-guns, Target, and Flobert Rifles.—Air guns use a 0.22 caliber lead bullet, with air as a propellant. The bullet causes a contused and lacerated wound. It has sufficient penetration to traverse some of the vital parts of the body. The knee, eye, and abdominal cavity have been penetrated with disabling and fatal results.

Target and Flobert rifles carry 0.22 and 0.32 caliber projectiles either round or cylindroconoidal. The latter are short or elongated. The 0.22 caliber bullet weighs about fifteen grains and the 0.32 caliber bullet weighs as much as sixty grains. The velocity of the U. S. Army target rifle which we use for gallery practice is 969 f.s. Fatal and disabling effects are frequently recorded in the literature from both of the foregoing weapons.

Fig. 2866.—Perforation by Marred Bullet from Colt's Automatic Pistol .38 cal. The jacket was not ruptured on impact. Range 5 yards, velocity 1107 f. s. Army Medical School collection.

Symptoms of Gunshot Wounds.—*Pain.*—The sensation on the receipt of a gunshot wound is referred to as a sudden rap, likened to the blow from a cane, which is often followed by a feeling of burning. The sensation is also compared to a sting from an insect, while all sensibility is blunted in a certain proportion of the cases and the wounded are not aware of any injury until their attention is called to it by a comrade or the sight of blood. Pain is more often felt at the wound of exit. There is often a sense of stiffness in the region hit, with pain on motion. When attended with great trauma, as a wound from a large shell fragment, or a high velocity rifle at close range, in which the parts are devitalized, the pain is blunted to the point of anesthesia in the wound and the tissues surrounding it. Pain is sometimes referred to at a point remote from the seat of injury. Thus, a man hit in the head, has complained of pain in the great toe, and in another, the referred sensation of pain was located in the foot when the injury was in the abdomen.

Constitutional Shock.—Shock is specially marked in wounds by gunshot that cause fracture with comminution; in body wounds, and most of the injuries from shells and shell fragments. The symptoms of constitutional shock are similar to those of shock from other causes. Instead of the mental apathy or anxiety and distress often seen in shock, in the excitement of battle there is occasionally seen a

form of shock attended with great excitement. It is apt to follow upon excitement which was agitating

Fig. 2867.—Radiogram Showing Lodged Pellets from Shot-gun Wound. Compound comminuted fracture of the fibula. (Army Medical School collection.)

the individual when the wound was received. In other cases there is the reverse condition. The injured seems to exercise a mental tension which apparently controls shock for an indefinite time. We knew a lieutenant of cavalry in the Sioux campaign of 1876 who showed the wildest kind of agitation after receiving a number of wounds, in a cavalry charge. He was leading his troop to seize an important position when he was shot. The charge was made with cheering and all the accompanying din of battle, and when he was badly wounded (three of the wounds were of a fatal kind through the body), the excitement under which he was laboring continued until death took place a half hour later. In another instance a captain of cavalry was shot by a Mauser bullet through the liver and right kidney at Guacimas during the advance on Santiago as his troop was slowly progressing through a terrain filled with undergrowth. There was no excitement nor charge, when a volley was unexpectedly fired into the command from a distance. The officer knew he was hit because he felt a sensation the same as if he had been struck by a stone and he saw blood flowing on his clothing. He was aligning his company when hit. He continued this work without stopping, and then without falling to the ground he walked a distance of seventy-five yards to a dressing station after which a certain amount of shock supervened.

Treatment of Shock.—The following cardinal facts should be kept in mind when dealing with a case of shock:

1. In shock the wounded should be carefully watched for the occurrence of hemorrhage which is prone to occur as soon as the blood pressure is reestablished.

2. If the temperature falls to about 96.8° F. the prognosis is grave.

3. The thermometer should be the guide for the proper time to operate. All the wounded who fail to recover their temperature in about four hours should be considered among the seriously wounded and unfit for operation.

4. No operation is permissible in a state of shock except the ligation of vessels to control hemorrhage, and transport should be delayed unless it is imperative.

The measures of relief for shock are directed toward restoration of the blood pressure. The patient should lie prone, the foot of the bed slightly elevated, warmth by means of hot water bottles and warm blankets should be applied externally, and brandy or whiskey mixed with hot water should be administered internally. Transfusion of saline solution with inhalations of oxygen are resorted to most successfully in some cases of profound shock. In the Russo-Japanese war the Japanese surgeons employed subcutaneous injections of camphor one part, ether four and one-half parts, and olive oil four parts. This was the favorite remedy on the firing line. In this country strychnine hypodermically is a favorite remedy, also injections of adrenalin with physiological salt solution in the proportion of five milligrams of the former to 500 c.c., of the latter injected in the cellular tissue behind the breasts or in the flanks.

Among the symptoms of gunshot wounds we have different forms of *hemorrhage* as (*a*) external primary, (*b*) recurrent, and (*c*) internal primary hemorrhage.

(*a*) External primary hemorrhage of the kind that is accessible to surgical intervention like that which proceeds from vessels in the neck and limbs is comparatively rare. It has become more so from wounds by the reduced caliber military rifles on account of the small track made by the ball which is easily obstructed by a change in the arrangement of the fascias and muscles involved in the traumatism. Bleeding takes place in the tissues causing frequent traumatic aneurysms to which we will refer later, but external hemorrhage of an alarming kind requiring ligation of vessels is rare.

(*b*) Recurrent hemorrhage has reference to the kind

Fig. 2868.—A Radiograph taken in 1911 of James A. Stewart, Co. "I" 81st Ind. Vol. Inf., and "G" 45th Veteran Reserve Corps, who was accidentally shot in the right hand by a hunter, Feb. 8, 1857, the shot entering the wrist and palm of the hand. The fingers are strongly flexed, and there is considerable atrophy of the muscles. U. S. Soldiers Home collection, Dr. A. B. Herrick, *x*-rayist.

of bleeding that takes place when temporary obstructions in the way of clot or intervening layers of tissue give way. It may be external or internal and it generally occurs on the second or third day.

(*c*) Internal primary hemorrhage is one of the frequent symptoms of gunshot wounds. It causes death in the vast majority of the fatalities on the field of battle. Unlike the vessels of the extremities those of the abdomen and thorax are unsupported by resistant tissues like fascia and muscle, and bleeding takes place freely in these large spaces until death ensues.

Thirst.—Thirst is an invariable accompaniment of gunshot wounds in war. Men are generally engaged in fatiguing marches in which but few opportunities to obtain water are at hand, and again soldiers know from experience that the ingestion of water on the march is hurtful and they school themselves to abstain from drinking. The experienced military surgeon is always on the alert to obtain water for his wounded before he comes in their presence, because water is one of the first things required to ameliorate suffering.

Infection of Gunshot Wounds.—We may assume that no gunshot wound is bacteriologically clean, and for reasons which we will touch upon later, we have to conclude that all gunshot wounds are infected whether the clinical evidences of sepsis are noted or not.

Infection is primarily found on all projectiles and since there is nothing in the act of firing that sterilizes the bullet, the wound becomes infected by the bullet itself. Furthermore we have shown that a bullet can gather infection from a dirty gun barrel or by ricochet before it enters the body. The liability to infection from shreds of clothing and particles of integument is well recognized, so that everything seems to combine to add to the chances of infection in gunshot wounds. The clinical evidence of infection is so nearly absent in some cases that wounds heal without apparent inflammation, and to all appearances the wounds seem to be sterile. Such a favorable outcome is due no doubt to the local and constitutional resistance of the individual as well as to the lack of virulence in the septic microbes. In spite of the apparent absence of inflammation, one will almost invariably find pus in and about the wound of exit especially. In military practice environment promotes the occurrence of sepsis. The injured are seldom left quiet as they are in fixed hospitals. In the emergent conditions following great battles, owing to shortage of relief personnel the wounded often lie unattended for hours in varying kinds of weather. Enforced transport is often necessary during which immobilization becomes difficult or impossible. The amount of disturbance to which the wounded are almost constantly subjected may be laid down as one of the prime causes of sepsis in field practice.

The character of the missile has a great deal to do with the development of sepsis. All wounds by shell, shell fragments, shrapnel balls, the larger caliber rifle projectiles, and deformed ricochet bullets are apt to show active suppuration, and the dangers of sepsis are very much magnified if there is fracture. Gunshot wounds of soft parts by the smaller calibers including the reduced caliber bullets of the present military rifles seldom show active symptoms of inflammation. When fracture takes place in wounds by the jacketed bullets, and especially at closes range the dangers of sepsis are the same as are seen in fractures from shell fragments.

The Virulent Infections.—Among the virulent infections tetanus is the most fatal and the most common. In former wars it has occurred in about one case in every 300 of the wounded as shown by the accompanying table. In more recent times it has been frequently found associated with the lesion of those wounds which are inflicted by blank cartridges. Schjerning reports thirty-four cases in the German army and other observers have noted it in wounds from blank cartridges which are more or less frequent

Tetanus in War. (By Mathieu.)

Wars.	Cases of Tetanus.	No. of Wounded.	Percentage.
British Army in India (1782)...	20	810	$\frac{1}{40}$ or 2.47
British Army in Spain (1811-14)	263	20,683	$\frac{1}{78}$ or 1.25
British Army in Crimea.....	26	12,904	$\frac{1}{496}$ or 0.21
Spanish Army in Morocco, wounded cared for in Africa..	1	56	$\frac{1}{56}$ or 1.78
Spanish Army in Morocco, wounded cared for in Spain..	4	3,920	$\frac{1}{980}$ or 0.10
French Army in Cairo (1798)..	7	200	$\frac{1}{28}$ or 3.50
French Army before Constantinople (1836).....	10	176	$\frac{1}{17}$ or 5.68
French Army in Crimea.....	120	39,868	$\frac{1}{332}$ or 0.30
French-Sardinian Hospitals (1859).....	153	21,967	$\frac{1}{143}$ or 0.69
Prussian Army (1864).....	14	1,968	$\frac{1}{140}$ or 0.71
Hanoverian Army after Langensalza (1866).....	13	1,092	$\frac{1}{84}$ or 1.20
German Army (1870–71).....	350	99,566	$\frac{1}{284}$ or 0.35
Austrian Army in Bosnia (1878)	16	3,878	$\frac{1}{243}$ or 0.41
United States Army, Civil War	505	246,712	$\frac{1}{488}$ or 0.20

in army maneuvers. In our own country toy-pistol tetanus is or has been of frequent occurrence until State laws were enacted to prohibit the sale of toy-pistols to minors. This source of tetanus occurred mostly among urchins on the street who amused themselves by firing toy-pistols, fire crackers, torpedoes and other explosives to celebrate the anniversary of our National Independence on July 4. The occurrence of tetanus from blank ammunition, toy-pistols, and all wounds from such weapons is due to the nature of the lesion more especially. The wounds are usually inflicted at or near the muzzle of the weapon. They show a great deal of laceration, hematoma, coagulation necrosis and all the conditions which are known to augment the tendency to the development of infections. Tetanus bacilli are so common with mobile armies and in the dust of the streets from the presence of horse manure that they find easy access to all wounds and the clinical evidences of this disease are very apt to develop in such wounds as we have just described. Gunshot wounds at best are contused and lacerated, and tetanus is naturally identified with this class of wounds in preference to the clean incised wounds from stabbing, or cutting instruments. Wounds by reduced caliber bullets at the battle ranges should show fewer cases of tetanus henceforth, but those received at close range, and the wounds from shell fragments, grenades, shrapnel, etc., which exhibit so many of the features necessary to the development of all kinds of infections will always be more or less identified with tetanus. In the Russo-Japanese war 300 cases of tetanus are reported by Follenfant[7] following the battle of Mukden with a mortality of eighty per cent. McPherson[8] calls special attention to the tendency to tetanus and malignant edema in wounds which resulted from the destruction of bomb-proof shelters and which were more directly caused by splinters from the beams that supported the earth sheltering.

Infection from the *Bacillus aerogenes capsulatus* ranks among the most virulent infections. Welch in his Shattuck Lecture has shown that infection from this organism is most frequently seen in compound fractures, and next in gunshot wounds.

We have reason to believe that infections from the more common pus-producing microbes acquire added virulency when frequently transmitted as they were in preantiseptic times from wound to wound. In the surgical practice of those times septicemia, pyemia, osteomyelitis, erysipelas, and hospital gangrene were the bane of all military hospitals. Instead of amelioration taking place in the character of the different infections as the war progressed, their

tendency to develop in the most trivial injuries seemed to augment with the duration of the war. In our Civil war from 1861–1865 the virulency of micro-organisms showed great tendency to suppuration, slough, and the development of a gangrene which was called hospital gangrene the exact etiological factor of which remains unknown to this day, and which only ceased to make its appearance when the war had ended.

Poisoned Wounds.—Although poisoned wounds from gunshot do not altogether result from infection, it is more convenient to treat them as a class with infected wounds. By the term poisoned wounds we have reference to the practice of placing a lethal dose of vegetable, bacterial, or chemical poison upon a bullet to add to the certain death of the victim. The practice of poisoning the implements of warfare like swords, knives, arrowheads, etc., is of ancient origin. It was a legitimate custom in the days of the Greeks and Romans. Poisoned arrows were used against man and beast. The Celts used certain poisons on their arrowheads in the hunt, among which was hellebore. The Vandals of North Germany are said to have used aconite as their favorite poison. The literature also records the use of poisons like curare which were fatal when introduced into a wound but innocuous by mouth.

In more modern times we are informed that the natives of Africa, the South Seas, India, and China followed the practice of poisoning their missiles and cutting weapons with decomposing viscera, snake venom, etc. The inhabitants of New Caledonia infect their arrowheads by dipping them in crab-holes. The victims wounded by arrowheads so prepared die of either tetanus or malignant edema.

Our work with septic bullets and septic powders[6] has shown that there is nothing in the act of firing a bullet or powder from a weapon which tends to sterilize either the bullet or the powder grains. We have succeeded in conveying anthrax spores, tetanus bacilli, and the various other germs into media and animals when fired from various weapons at all ranges up to 500 yards. Death ensued in the majority of the animals showing that the particular poison used was not destroyed by the act of firing, setting aside a popular notion that bullet wounds are for the most part sterile because of the heat that is imparted to the bullet by the act of firing. The experiments which we made by placing vegetable and chemical poisons on bullets and powders were just as positive.

Treatment of Gunshot Wounds.—The treatment of gunshot wounds at the beginning is directed toward the management of shock, arrest of hemorrhage, and the prevention of infection.

The management of shock has already been considered. External primary hemorrhage from vessels in the extremities or neck is treated by ligation. If this cannot be done at once first aid resources should be employed, such as elevation of the injured limb, extreme flexion, digital compression, and pressure by packing with antiseptic tampons. When these are not sufficient, constriction whenever it can be applied, should be resorted to. The limb should be rendered as bloodless as possible by gravitation before constriction is made. In the absence of a regular tourniquet an elastic bandage, a Spanish windlass, or a pair of suspenders will answer the purpose. After the limb has been elevated the constriction should be rapidly applied with sufficient force to prevent the flow of blood through the vessels at the point of pressure, but it should not be maintained longer than three or four hours lest gangrene or paralysis is brought about. It is better to keep cases in which constricting bands have been applied under the watchful care of the surgeon until the apparatus has been removed. *Recurrent hemorrhage* from giving way of temporary obstructions like a blood clot or the remaining wall of an injured vessel, a kind of bleeding that is apt to appear from one to three days after the receipt of the injury, is generally treated by ligation. The treatment of *internal primary hemorrhage* in body cavities will be more especially dealt with when dealing with injury to the chest and abdomen. The treatment of *secondary hemorrhage* is prophylactic and by ligation. The invasion of septic microbes is the principal cause of secondary hemorrhage and in preantiseptic times this form of hemorrhage was very common and one of the frequent causes of death.

With our modern method of antiseptic treatment we now prevent secondary hemorrhage as a result of sepsis. Late forms of hemorrhage which may be classed as secondary hemorrhage sometimes take place, especially in the military service during enforced transport, as a result of injury to blood-vessels, from puncture of a vessel by a jagged spiculum of bone, or final rupture of an injured vessel's coat from jolting in all kinds of vehicles over rough roads. The treatment in secondary hemorrhage is by (*a*) ligation of the vessel in the wound, (*b*) ligation of the main artery of the limb above the wound, (*c*) amputation. Secondary hemorrhage from an injury to a blood-vessel by a spiculum of bone or final rupture of a weakened vessel from previous injury is generally arrested by ligation of the vessel in the wound.

When hemorrhage occurs as the result of a septic process a tourniquet should be applied at once and the wound should be opened up and explored for the bleeding vessel. The surgeon should be sure that he is applying his ligature to healthy tissue and if any doubt arises he should expose the artery until the sound part of the vessel comes into view. The wound should next be drained and thoroughly irrigated with antiseptic solutions like mercuric bichloride 1–4,000 or carbolic acid 1–40. If the bleeding appears to be an oozing from a particular part of the wound the hot iron may be used, and also, when it is difficult to find a healthy vessel to tie conveniently the hot iron may be used very successfully if the vessel is not too large. If the bleeding vessel is in one of the extremities the rule is to ligate on the proximal side of the wound. When the hemorrhage persists after ligation or if gangrene sets in amputation should be resorted to. Proximal ligations succeed better in the upper extremity, but irrespective of the extremity that one is dealing with, amputation is in order when ligation fails.

Prevention of Infection.—The prevention of infection in the emergent conditions of war has received a great deal of attention in recent years. The relief personnel of armies is taught never to allow their fingers or anything else to come in contact with a wound except a clean dressing which is carried by every soldier. The dressing in the United States Army is carried on the cartridge belt in a metallic hermetically sealed case. It is made up of two bundles of absorbent sublimated (1–1,000) gauze four by eighty-four inches long, two compresses of absorbent sublimated (1–1,000) gauze, each composed of a half square yard so folded as to make a compress three and a half by seven inches, and two large safety pins wrapped in wax paper. The compresses and pins are wrapped together in tough paper in which are included printed directions for the use of the dressing. Until recently we applied this dressing to the wound with no attempt to cleanse the surface or the wound. Now we first paint tincture of iodine or Lugol's solution over the wound and adjacent skin, being careful not to let the iodine collect in the recesses of the wound when present, and then apply the dressing. For large lacerated wounds it may be necessary to use the contents of several of the first aid packages. The difficulties of transporting tincture of iodine or Lugol's solution already prepared are met by including the following preparation in the field equipment: a cardboard carton containing ten hermetically sealed glass tubes and a four-ounce bottle are carried by every member of the

hospital corps, and there is included in each tube 1 gram of iodine crystals and 1.5 grams of potassium iodide. By putting the contents of two tubes in the bottle and then filling the latter with water or alcohol one makes a two per cent. solution which is sufficient to sterilize the skin for first aid work. Lugol's solution thus prepared has the same antiseptic value as the tincture. By carrying a preparation with which to make the solution or tincture at will, we overcome the difficulty which would arise from the absence of water or alcohol, not an infrequent complication in field practice.

Aside from the clean dressing of a wound, immobilization of all gunshot injuries plays a very important role as a prophylactic against wound infection, and besides, in cases where enforced transport becomes necessary, it adds much to the comfort of the patient, it helps to prevent the recurrence of hemorrhage, and it favors early healing. Soft parts are immobilized by means of slings, a firmly fitting bandage, or splints. In wounds of the chest or abdomen a tight bandage around the body will give comfort, but the great value of immobilization is in gunshot fractures. Whether there is a distinct solution of continuity or not immobilization should always be practised. Bone injuries in the way of grooves or furrows with slight fissures radiating from the point of impact will soon be converted into complete fractures with attendant displacement unless the precaution of immobilizing in all cases is adopted. Minor bone lesions like perforations, furrows, and butterfly-fractures in which the fissures are at first only subperiosteal are not uncommon as a result of gunshot by jacketed bullets, and the principle of immobilizing in all bone lesions is more imperative now than it was in the days of the old armament.

In the presence of a gunshot wound the following rules for the prevention of infection are worthy of note: (*a*) paint the wound and surrounding skin with tincture of iodine or Lugol's solution and apply a clean dressing; (*b*) it is better not to attempt to disinfect the wound proper during emergent conditions or on the battlefield; (*c*) never probe a gunshot wound with finger or instruments however sterilized; (*d*) never transport the severely wounded unnecessarily; (*e*) immobilize in all gunshot wounds, and in bone lesions with or without fracture, maintain immobilization until a fracture has had time to unite.

After the application of first aid resources it is sometimes necessary to employ further treatment. This is generally instituted in a fixed hospital where all the means for the proper care of the injured are at hand. Here a thorough examination should be instituted if necessary and the measures of relief will have to be guided by the symptoms, *x*-ray findings, etc. This will always include redressing, the proper use of antiseptics and drainage in cases of existing infection. The fixed or base hospital will also be the proper place for removal of foreign bodies, loose fragments of bone; laparotomies, excisions, amputations, the administration of food and stimulants, ligation for traumatic aneurysms, hemorrhage, and the treatment of secondary hemorrhage.

As long as there are no indications for interference the wound should be let alone. One should never interfere except in the case of a lodged ball which may be causing pain, and in the case of a gunshot fracture where infection has set in. In such a case the surgeon should cut down boldly, establish tubular drainage, remove free and infected fragments of bone, lodged material, and the liberal use of antiseptic solutions should be employed. When intermittent irrigation fails to check the septic condition continued irrigation of a saturated solution of acetate of lead as recommended by the late Nicholas Senn should be employed. As soon as union of the broken bones has commenced to take place the temporary methods of immobilization should be replaced by a fixed plaster-of-Paris cast and the patient should be encouraged to walk or be wheeled into the open air.

Secondary hemorrhage which was so common in the war hospitals of the preantiseptic era is now seldom seen. But secondary hemorrhage from gunshot may appear from a grazing shot to a vessel which impairs its outer coats when the remaining coat gives way and causes bleeding some days after the receipt of the injury; or, a secondary or recurrent hemorrhage is not infrequent when a temporary obstruction from an intervening layer of tissue or clot gives way. Again in transport a jagged edge of bone may lacerate a vessel and cause a secondary hemorrhage.

Treatment of secondary hemorrhage from any cause is by ligation of the vessel in the wound, ligation of the main vessel above the wound, or amputation. When the vessel cannot be found in the wound and the bleeding seems to ooze from one particular locality, the actual cautery is often successful. When hemorrhage persists after all methods have been tried, or if gangrene sets in, amputation becomes necessary.

Removal of lodged missiles is best accomplished after the wound has healed and the exact location of the foreign body has been ascertained by *x*-ray evidence.

Wounds of Special Regions.

Wounds of the Head, Face, and Neck.—*Gunshot wounds of the head* are divided into (1) those of the scalp; (2) those of the skull without lesion of cranial contents; (3) those attended with brain injury.

(1) Wounds of the scalp need not occupy one's attention unduly since they are rarely fatal and seldom require more than first aid attention. In the records of our Civil War the fatalities were 2.09 per cent. out of 7,739 scalp wounds, but these are attributed to erysipelas, meningeal inflammation, gangrene, pyemia, and other infections that are most generally avoided by our modern methods of wound treatment. The French troops in the Crimean War sustained a loss of ten per cent. of their scalp wounds (Chenu), but doubtless a large proportion of these fatalities can now be assigned to unrecognized cranial injuries. Particular attention should be paid to the first dressing of a scalp wound to avoid sepsis. The dirt of the scalp is proverbial and all scalp wounds are followed by infection unless extreme care is observed to avoid it, and this applies especially to lacerated wounds from shell fragments, deformed bullets, and glancing shots from shotguns. The hair should be shaved and the scalp thoroughly scrubbed with nail brush, soap, and water, and a liberal use of antiseptic solutions like bichloride of mercury 1–2,000, or carbolic acid one to twenty should precede the primary dressing. In field practice or emergent conditions in civil communities where the necessary facilities are not at hand, the shaved scalp and wound should be painted with tincture of iodine just before the application of the first dressing.

(2) Shot wounds of the skull without lesion of cranial contents will include contusion of the skull, fracture of the outer table alone, and fracture of the inner table alone.

Contusion of the skull in former wars was caused by slow moving projectiles like lead rifle bullets and pieces of shell with smooth surfaces. The latter and shrapnell balls are the frequent causes of the lesion in the wars of the present.

Fracture of the outer table alone is of rare occurrence except over certain cranial regions like the frontal sinus, the mastoid and zygomatic process of the temporal. Injury to other regions of the skull is most generally accompanied by involvement of the inner table. Injuries to the outer table in this respect are alike for the old and new armaments. Except for the regions above mentioned, a grazing shot of the skull by the reduced caliber bullets of our present military rifle, or the steel-clad bullets of the high

velocity automatic pistol, will invariably show fissures or fragmentation of the inner table accompanying the lesion of the outer table.

Fracture of the Inner Table Alone.—Only twenty such cases are said to have occurred in our Civil War and ten of the specimens are now on exhibition in the Army Medical Museum at Washington. Figs. 2869 and 2870 are typical examples of these cases.

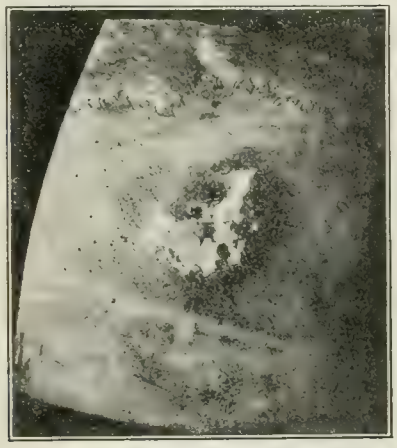


Fig. 2869.—Photograph of Outer Table of Skull showing contusion without fracture by a conoidal musket ball.

The cases referred to were caused by oblique impact of musket balls mostly, some of shell fragments, and one by a buck shot. These missiles did not have enough energy to fracture the outer table. They caused the latter to yield and the pressure so exerted on the inner table ended in fracture of it, after which the outer table resumed its normal curvature. The superior penetration of the jacketed rifle and automatic pistol bullets of the present day, except when they act as spent balls, invariably fracture the outer and inner tables at the same time.

Gunshot Fracture of the Skull with Attendant Brain Injury.—In this kind of lesion there is fracture of the inner or both tables with injury to cranial contents.

Fig. 2870.—Inner Table of Same Skull with Fracture. A fragment an inch and a half in length and half an inch broad completely detached from vitreous table. Specimen from Civil War 1861–65. Army Medical Museum collection.

These injuries are very fatal, they are attended with definite complications and sequelæ, and they require prompt and radical measures of treatment. The fatality of these head injuries in war was 59.2 per cent. for the Civil War; 51.3 per cent. for the Franco-German War of 1870-71; and 51.3 per cent. for the Spanish-American War and Philippine Insurrection. The fatality in the Anglo-Boer War according to the British returns was 29.4 per cent. in 136 cases of gutter, penetrating, and perforating fractures of the head. Their results are far better than those of the U. S. Army returns in the Spanish American War under modern conditions. The discrepancy is so great that it is more than likely due to the manner of registration on the field by the relief corps of the two armies. We have reason to believe that our returns were made up from all the cases as they occurred at the front and along the line of communications, while the returns of the English included only those that lived to reach hospital care.

Gutter Fracture.—This form of fracture with attendant brain injury is common with the use of steel-clad bullets from reduced caliber rifles and automatic pistols. The scalp is slit in the superficial fractures of the skull, but the deeper injuries are more frequent; they exhibit wounds of entrance and exit which mark

Fig. 2871.—Photograph of John G., Jr., late Private, Co. "D," 1st Neb. Vol. Inf., taken thirteen years after receipt of injury. Scar from wound entrance shows on forehead above inner canthus, left eye. Army Med. School collection.

the limit of the bullet's track. The shock of impact from the high velocity bullets is so great in the deeper gutter lesions that the energy which is transmitted to the outer table invariably causes fracture of the inner table as well. Under prompt measures of treatment these minor lesions have a favorable prognosis.

Penetrating Fractures.—In this class of gunshot wounds of the head there is a wound of entrance and no apparent wound of exit. The missile generally finds lodgment in the skull, though it has been known to lodge down the neck, and with lead bullets of low velocity, the projectile will at times flatten against the skull and there find lodgment. Penetrating fractures are not as common now as they were in the days of the old armament. Otis, in the Surgical Volumes of the Medical and Surgical History of the War of the Rebellion makes note of 486 cases for the whole war, and missiles were extracted from within the cranium in eleven cases. Penetrating fractures of the skull are only

noticed from the steel-clad projectiles of the present day when these have lost the greater part of their remaining velocity. The following case from the Spanish-American War of a lodged Mauser in the brain substance is of special interest because of the number of years that the patient has carried the bullet at the same time that he has pursued his duties as a post-office official, and also because the history is accompanied by a recent picture of the bullet *in situ* and a photograph of the patient.[1] (Figs. 2871 and 2872.)

Case 14.—Penetrating, Mauser-bullet wound of brain; wound aseptic; bullet removed. "John G. Jr., private, Company "D," First Nebraska Volunteer Infantry, wounded at long range, March 27, 1899, at Mariboa, Philippine Islands, by a Mauser bullet entering cavity of cranium, three-fourths inch above the supraorbital ridge and one-fourth inch to the left of the median line. There was a total loss of consciousness during first few hours following receipt of the traumatism, with the exception of a few short intervals of semiconsciousness, at which time excruciating pain in the head was experienced. The patient was taken to the First Reserve Hospital at Manila, where he lay in bed for about four weeks. While in bed, he suffered extremely from pain in the head, most severe the first three days, moderating slightly; at the end of the fifth week becoming intermittent, greatly exaggerated on exertion, by heat, and especially by direct rays of the sun, exposure to which caused him to reel, stagger, and almost lose consciousness. At the present time (August, 1899) is still quite susceptible to direct rays of the sun. First few days of illness were marked, by extreme nausea and persistent vomiting; the slightest thing taken in the stomach would be rejected. The pain in the head increased the severity of these attacks. During early weeks of illness any exertion of the brain, as reading, caused pain in back of eyes and vertex of the head. Returned to San Francisco with his regiment in August, 1899. Radiograph taken August 20 showed Mauser bullet embedded in left occipital lobe."

"Condition October 1, 1899, six months after receipt of the injury: Occasionally has pain in the lumbar region, and describes it as being a "catch," lasting about five minutes at a time. Pain in the head, when present, is located a little anterior to parietal eminence on left side. There is no history of loss of power on either side, but a weakness is appreciated in the right arm and leg, and a slowness in response to mental impulse. This last is demonstrated in the act of writing; though the thought is perfectly clear, there is a slowness in the forming of the words."

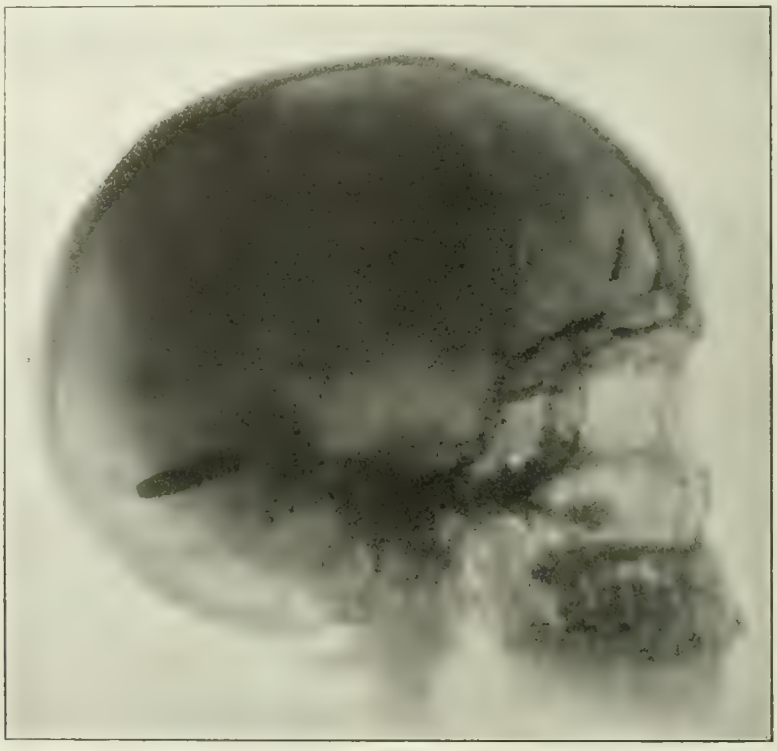


Fig. 2872.—Latest Skiagram of John G., showing present location of Mauser bullet in brain. Exposure made in 1912, thirteen years after injury. Army Med. School collection, Gibbs Laboratory. Dr. Leon T. LeWald, X-rayist.

"Voice: Patient did not, to his knowledge, exercise this function for first two days of illness, but on beginning to do so, noticed a slight confusion of ideas, it being necessary first to clearly fix a thought before giving expression. There was also temporary loss of power to recall past events and names of companions. This returned with full clearness at other times. A slight confusion still remains."

"Eye: Pain back of left eye is less severe, increased by use, and relieved by closing the lid. During confinement to bed following injury, patient tested vision of left eye by closing right. The vision was clear, but slight weakness and photophobia was noticed. Ptosis of left eye marked during early weeks of illness. Aperture is now smaller than that of right eye. A slight diplopia was also present, a line of printing appearing double. Pupils are regular, but left slightly larger. Reaction to light and power of accommodation is noticeably decreased, especially in left eye. Visual field normal. No nystagmus."

"Hearing is normal. Sense of taste more acute on

right side, the anterior two-thirds of left side showing marked dullness.

Tactile sense seemingly slightly dull on right side. General sensation of right side not as acute as on opposite side.

"Reflexes: Knee reflex very marked on right side, responding to touch above, as well as below the joint; the contact from finger causing a disagreeable tingling throughout the thigh. On left side, reflex is exaggerated, but not to such a marked extent. Wrist reflex marked on right side, causing a chronic spasmodic contraction of the fingers. Reflex absent on left side. Ankle clonus and patellar reflex absent. Cremasteric marked on both sides. Sphincters uninvolved at any period of illness; coordination good, though a slight uncertainty is felt on attempting to walk with the eyes closed. No epileptiform seizures. No disturbance of nutrition or bodily functions.

"The patient later entered the mail service and returned to Manila on duty." Reported by Major A. C. Girard, Surgeon, United States Army, General Hospital, Presidio.

Mr. G. is now employed as a clerk in the Postoffice Department. In a recent letter he writes of his condition as follows:

Postoffice Department,
Office of the Inspector in Charge,
New York, N. Y., Oct. 13, 1911.

Colonel Louis A. LaGarde.
Commandant, Army Medical School,
Washington, D. C.

My dear Sir:

I am in receipt of your favor of the 9th inst. relative to gunshot wound of head, received by me during my service in the Philippine Islands. I regret that I am unable to furnish you with a medical history of my case since leaving the Presidio General Hospital.

I have not received medical treatment for my wound, as I realized aside from an operation but little relief could be afforded, and my condition has not justified that, inasmuch as a consultation of army surgeons at the Presidio Hospital decided that an operation would probably prove fatal. The symptoms from which I suffer as a result of bullet carried in brain are about the same as when discharged, except stooping causes severe pains in the head. This is also true of a sudden jar. My wound appears to be affected by a change in weather, general health good.

I will be pleased to furnish you any further information desired and appreciate the interest you have taken in my case. I am enclosing a couple of newspaper clippings in connection with my case, which may be of interest.

Yours sincerely,
(Signed) John G., Jr.

The following case exhibiting a lodged Krag-Jorgensen bullet is taken from the records of the hospital Madison Barracks, New York: J. S. P. Private, "K" Company, 9th U. S. Infantry, æt. twenty-eight, admitted July 23, 1903. "Accidentally shot by firing party at 500 yards range, ball ricocheting on butt timber and striking patient while in target pit at Stony Point Rifle Range, New York, July 23, 1903, as per transfer slip."

A diagnosis was made at the Hospital of "Gunshot

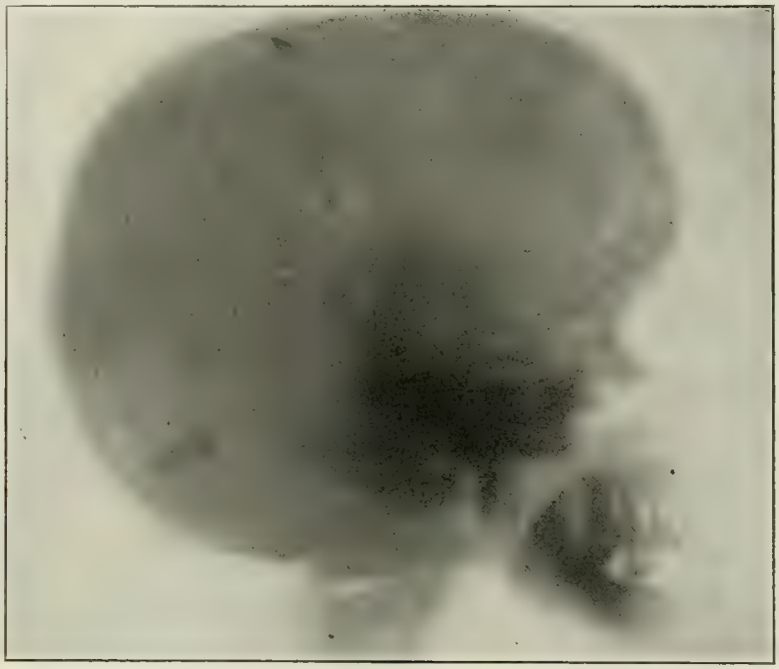


Fig. 2873.—Skiagram in Case of Private J. S. P., Co. "K" 9th Inf., showing a Krag-Jorgensen bullet lodged on the tentorium. Army Med. School collection X-ray Laboratory.

fracture skull, right parietal region, Krag-Jorgensen bullet, severe, causing partial hemiplegia, left side. Entrance wound four inches above right external auditory meatus and four inches from right external angular process of frontal bone, ball penetrating brain, no exit wound." Under chloroform anesthesia numerous pieces of bone were taken from the entrance wound, a bleeding vessel was ligated; brain lacerated, bullet not found. Scalp wound was sewed with silkworm gut and dressed antiseptically. Sent to quarters August 23. The patient was later discharged from the service, but he was readmitted to the same hospital June 3, 1904, for cerebral abscess posterior parietal lobe. He died the same day. At autopsy ball was recovered on the tentorium in the position indicated in the skiagram, Fig. 2873. After discharge from the service Jan. 28, 1904, the patient suffered from partial paralysis left side face, and left hand; headache and vertigo, for which he was borne on the pension rolls until his death June 3, same year.

Perforating Fractures.—In this class of cranial injuries we have a wound of entrance and a wound of exit. Such injuries are extremely fatal, since the

majority do not live to reach hospital care. At the battle of Santiago we found that shots passing through

Fig. 2874.—Photograph Showing Side View in Case of Patrick D. Army Med. School collection. Ft. Sheridan X-ray Laboratory.

the posterior two-thirds of the skull in any direction near the base, were generally fatal, and, that the degree of fragmentation was in proportion to the remaining velocity and energy of the projectile.

The extreme explosive effects of our present day rifle ammunition is strikingly exhibited in the case of Private Patrick D., Co. "K" 27th U. S. Infantry, who shot himself Nov. 13, 1911. The muzzle of the piece was held in his mouth or near it while the barrel was directed toward the vortex of the skull. Col. Charles Wilcox, M. C., U. S. A., who reports the case states that "the entire squad room, especially the ceiling, was stained with blood and fragments of brain." The great destruction of soft parts destroyed all appearances of a wound of entrance or exit. The face above the lower jaw; the entire cerebrum and cranial vault were blown away. Doubtless the expanding force from the gases liberated by the propellant added to the explosive effects, but aside from the pressure exerted from this source, we know that the energy from the projectile and the energy which it conveyed to secondary missiles like pieces of bone, dura, and particles of brain tissue are quite sufficient to cause the bulk of such a lesion.

Fig. 2876 exhibits the appearance of the skull in a man who was shot with a Krag-Jorgensen bullet by a member of the guard at Fort Sheridan, Illinois, at a distance of ninety feet. After passing through the man's skull posteroanteriorly it perforated a tree eight inches thick and buried itself two feet in the ground. The patient lived only one hour after he was shot. The wound of entrance was round the size of the bullet, that of exit was larger and ragged. The destruction of brain tissue was extensive, corresponding to the violence which is exhibited in the skull. The explosive effects would have been more marked had the bullet traversed the head nearer the base where the greatest amount of resistance lies. In addition to the fissures which are shown in the photograph, there was comminution of the cribriform plate, fissures in the petrous and temporal portions of the temporal bone, otherwise the skull was intact.[9]

The automatic pistol bullets which are now becoming so popular in civil communities have decided shattering effects on resistant parts of the body like the cranium as compared to the bullets of similar calibers and lower velocities from lead bullets shot from revolvers. The lead bullets from the latter are prone to inflict penetrating wounds with lodged balls. This is even so when the weapon is held near the head when fired.

Aside from the fact that the 0.38 caliber Colt's revolver bullet had a comparatively low velocity, it failed to perforate the head on account of the deformation which it sustained on impact against the frontal bone. When its sectional area was thus increased it at once lost its penetration, and the result was lodgement of the bullet. This bullet might have perforated very readily at eight or ten yards away. The remaining velocity would have been less, and the bullet would have been more likely to penetrate the frontal bone without deforming and it might then have had sufficient force left to carry it through the head without lodging.

The effects of superior velocity and energy from steel-clad bullets out of an automatic pistol strikingly shown in Fig. 2878. Although the caliber of the bullet which inflicted this injury was much less, the shattering effects are far

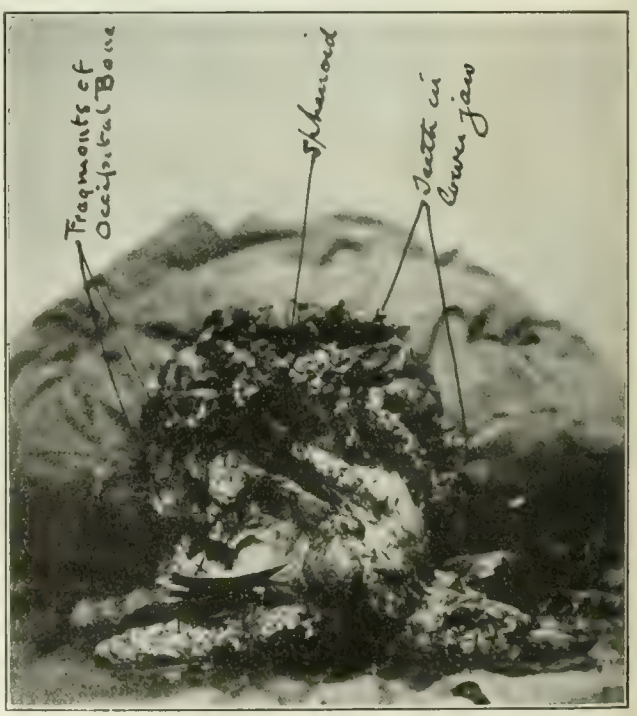


Fig. 2875.—Posterior View of Fig. 2874.

more extensive and these have to be ascribed to the superior velocity and energy of the short unstable

bullet from the Luger pistol. For ballistics of pistols and revolvers see Table II, p. 803.

Remote Effects of Head Wounds.—But few gunshot injuries, whether they are attended with contusion or fracture, fail to give evidence of cerebral disturbance. Cicatrices are at times painful enough to require excision. But the more persistent remote symptoms of head injuries are headache, dizziness, and irritable disposition, which are especially prone to appear when the patient resumes his vocation. There are also paralytic symptoms which are worse at first with a

Fig. 2876.—Army Medical Museum Collection. No. 10910 pathological series.

tendency to improve with time. Headache and dizziness especially are aggravated in hot weather and during residence in the tropics. Physical and mental work are soon followed by fatigue. Patients are disturbed by trifles and they exhibit neurasthenic tendencies. All the symptoms of nerve irritation are aggravated by the use of alcohol. The memory is impaired, there are at times marked changes in the character of the individual. Those of a cheerful disposition become fault-finding, moody, eccentric, and irascible. Epilepsy is frequently noted and insanity supervenes at times.

The *complications* of gunshot fracture of the cranium are concussion, compression, and hemorrhage; and, as sequelæ we have meningitis, encephalitis, hernia cerebri, and brain abscess.

Concussion, Compression, and Hemorrhage.—The differentiation between concussion and compression is not easily made in the beginning, since the symptoms are very much the same. It should be remembered that concussion is rare in gunshot wounds of the cranium, and that it is generally but transient when it results from contusion, guttering, or the minor gunshot lesions about the skull. Symptoms due to penetration or perforation accompany those of compression when the latter is present. Symptoms of compression from depressed bone come immediately, while those from hemorrhage are more gradual in their onset. Subdural hemorrhage comes on gradually also, and it generally results from fissure in the track of the middle meningeal artery with rupture of the latter.

Meningitis, encephalitis, hernia cerebri, and brain abscess are the result of infection and usually end in death. Hernia cerebri may follow rupture of the dura as a result of pressure from depressed bone but most generally it is caused by penetration by the projectile. It is either primary or secondary. The primary form is nearly always fatal, it is due to pressure from internal hemorrhage which takes place through a large opening in the dura soon after the receipt of the injury. The secondary form occurs later; it is the result of internal pressure from the products of inflammation ending in abscess, meningitis, or encephalitis.

Otis reports fifty-five cases of secondary hernia cerebri during our Civil War with a mortality of eighty per cent. Under modern methods of treatment the mortality in the Anglo-Boer War was only 41.9 per cent. in twelve cases according to Stevenson.

Treatment of the secondary form of cerebral hernia consists in the persistent application of a clean dressing applied with moderate pressure. Absolute alcohol is a favorite remedy with most surgeons. It is painted on the tumor daily for its cleansing and dehydrating effects. Excision and cauterization are practised, but they are attended with a certain amount of danger. Gangrene and spontaneous separation sometimes result in cure.

Abscess of the brain usually occurs about the second or third weeks. The symptoms are not always definite and they are generally slow in developing. There are a rise of temperature, headache, chill, nausea and vomiting, also drowsiness. Choked disc is frequent, and slow pulse is significant. Jacksonian epilepsy appears in some cases.

Treatment of Gunshot Fracture of the Cranium.—Prompt operative interference should be undertaken in all gunshot fractures of the cranium that offer any hope of recovery. As a class, fractures of the cranium are necessarily infected in every instance and unless immediate and effective measures are undertaken to cleanse the wound of entry, and that of exit if one is present, infection with its attendant dangers is sure to appear. Infection enters the wound primarily from the dirty scalp, hair, and infected bullet. Every effort should be made to remove dirt, pieces of loose bone, and metallic particles from the wounds and the channels leading from them. The scalp should first be shaved clean with a razor if possible and in the absence of a liberal amount of antiseptic solution, the wound and surrounding surface should be painted with tincture of iodine or Lugol's solution. A flap of scalp should next be raised at the wound of entrance with its convexity directed in the best way to secure drainage, the wound of entrance forming the center of the flap. If sufficient room is not available to explore the vicinity of the injury the orifice in the skull should be enlarged with the rongeur. All fragments of bone and foreign matter should be removed and disintegrated brain pulp and blood clots should next be washed away. The wound in the scalp should then be closed by suture preferably without drainage. If drainage becomes necessary at any subsequent time it can be easily accomplished by relieving some of the sutures at the most dependent part of the incision.

Primary union is preferable since it wards off the danger of sepsis that might so readily enter an open

wound. The wound of exit is generally larger, and readily accessible for exploration. It should be cleansed like the wound of entrance and preferably closed. Gutter fractures should be made smooth with rongeur forceps and the floor of the gutter, composed of the inner table should be freed of all fragments. Depressed fractures without complete penetration of the projectile in the skull are treated by replacing the fragments still attached and loose fragments should be removed entirely. Particles of the inner table that make pressure on the dura or brain should also be removed. It is a safe rule to explore all gunshot injuries of the cranium whe her fracture is apparent or not, and in cases of doubt there should be no hesitancy in removing a half-inch crown to secure proper exploration. In cases that are not thoroughly explored the subsequent history often reveals fracture, with fatal results.

The treatment outlined above was faithfully followed by the British surgeons in the Anglo-Boer War and their efforts were rewarded by the very low average mortality of 29.1 per cent. in a list of sixty-three gutter, thirteen penetrating, and sixty perforating fractures of the cranium.

Removal of Lodged Missiles.—Unless accompanied by annoying symptoms the removal of lodged missiles should not be undertaken, and no attempt at removal should be made unless the location of the bullet has been definitely ascertained by *x*-ray evidence.

Wounds of the Face.—Wounds of the face when inflicted by large caliber projectiles are attended with varying degrees of disfigurement. If the reduced caliber bullet traverses the upper part of the face above the alveolar processes a clean cut perforation only is apt to result with little or no disfigurement. Impact against the body or ramus of the lower maxilla is attended with much splintering and deformity depending upon the remaining velocity of the bullet.

Wounds of the Neck.—Wounds of the neck exclusive of injury to the vertebral column gave a mortality of fifteen per cent. in a total of 4,114 neck wounds in our Civil War, 1861–65. Those of the larynx, trachea, and pharynx were especially fatal with the use of the old armament. The beneficence which has resulted from the employment of the steel clad reduced caliber bullets in recent years is particularly exhibited in gunshots of the larynx, trachea, and pharynx.

Fig. 2877.—Skiagram Showing Perforating Practure of Head by Colt's new service revolver .45 cal. lead bullet at close range in cadaver, brain *in situ*. Ball flattened, lost its penetration and then lodged. Note particles of lead in track of bullet. Army Medical School collection.

We saw instances in the Santiago campaign in which the larynx, trachea, and great vessels were all in turn perforated without fatal outcome. Of 133 cases of gunshot of the neck that lived to reach hospital care, for the whole of the Spanish-American War the mortality was eighteen per cent. Two of the fatal cases were operated upon for subclavian aneurysm.

Septic pneumonia sometimes complicates gunshot of the larynx and trachea. Hemorrhage from injury to vessels of the neck should be treated by ligation above and below the wound. The wounded from shell fragments seldom live to reach hospital care. Injury of the large vessels of the neck by reduced caliber steel clad bullets very frequently causes one of the forms of traumatic aneurysm. A certain percentage of the cases will be attended by a temporary spurt of blood, and when the patient is kept quiet the wound in the vessel will close, and healing will take place without any other symptom. If the case is attended by recurrent hemorrhage, the surgeon should at once cut down upon the bleeding vessel and ligate above and below the wound. Unless this is done very promptly, swelling will take place in the tissues causing a diffuse aneurysm that will

destroy the normal relation of the parts to such an extent that ligation later will become very difficult. To temporize with pressure and the use of styptics, which constituted the old time treatment in such cases, is fatal. The surgical practice at present is to cut down and tie the bleeding vessels in the wound whenever this is possible. This will be a difficult thing to do when the bleeding is above the bifurcation of the common carotid in the parotid region. In such a case the surgeon should expose the origin of the two arteries and then successively compress the vessels, and tie the one which controls the hemorrhage when pressure is made. If the hemorrhage fails to stop when the vessels are alternately compressed, the rule is then to tie both the internal and external carotids. As an additional precaution to prevent the recurrence of hemorrhage the skin incision should be enlarged and the wound packed with antiseptic tampons.

Fig. 2878.—Photograph of Gun-shot Fracture of Cranium in Cadaver with brain *in situ* by the Luger automatic pistol bullet, cal. 765 mm. at 37 1/2 yards, with velocity of 1258 f.s. Bullet entered left orbit and emerged above and behind right auditory meatus fracturing left malar, orbital surface superior maxillary, ethmoid, body and great wing of sphenoid, vomer; separated the right malar, fracturing frontal over orbit, right parietal, petrous, squamous, and mastoid portions of right temporal, left parietal, and left occipital bones. Philadelphia Polyclinic, service of Dr. A. Hewson.

Wounds of the Jugular Veins.—Wounds of the external jugular vein require ligation of both ends of the vessel in the wound. Wounds of the internal jugular were very fatal by the old armament under the methods of wound treatment that prevailed formerly. Under modern conditions the same wounds are treated more successfully when seen in time. In the case of a vein that has been hit at a tangent by a reduced caliber bullet, and which is easily accessible, application of fine sutures to the margins of the wounded vessel is a recognized procedure. In vessels with smaller wounds, the edges of the wound can be brought together with a hemostat which should be left *in situ* for a few days. Larger vessels that are perforated by the projectile require ligation of the vessel above and below the point of injury the same as practised for a wounded artery.

Wounds of the Nerves of the Neck.—Unlike injury to nerves of other regions there is little that can be done in a surgical way for nerve injuries in this locality. Injuries to the seventh, the recurrent laryngeal, and spinal accessory cause paralysis of the muscles in their distribution with interesting clinical signs. Injuries to the phrenic nerves are the most serious; there is paralysis of the diaphragm on the corresponding side, with hiccough, dyspnea, and a sensation of constriction around the body.

In rare instances injury to the pneumogastric alone is noted. On account of the intimate relation to the great vessels the latter are most generally implicated. Aside from direct traumatism the nerve

may be injured by pressure as in cases of aneurysm or by the vibratory force which is transmitted by the projectiles of the high power military rifles in present use. Injury to this important nerve has interesting clinical signs such as difficulty in deglutition, phonation, and respiration; irregularity and rapidity of heart action occur later, and often cause death. Injury to the pneumogastric is doubtless a frequent cause of death on the field of battle among those hit in the neck.

Fig. 2879. Photograph of Cadaver showing course of bullet in case of Capt. C. A. T., 9th U. S. Cavalry.

Now that aneurysm is more frequently noted from the use of reduced caliber bullets, vagus involvement by pressure will be more frequent than formerly.

Wounds of the Cervical Sympathetic.—Uncomplicated injury to this nerve is seldom seen on account of its intimate relation to other important structures. In rare instances the nerve alone has been injured, and the symptoms of injury to it have also been studied in cases where primary hemorrhage from the adjoining large vessels has been successfully arrested. Upon complete division the following symptoms are commonly noted: (*a*) narrowing of the palpebral fissure; (*b*) sinking of the eyeball; (*c*) contracted pupil; (*d*) loss of the ciliospinal reflex, and (*e*) redness and dryness of the skin of the corresponding side of the face. In partial division of the nerve only some of the foregoing symptoms are seen.

Wounds of the brachial plexus are among the more common nerve injuries of the neck by gunshot. They are attended with protracted suffering as a result of neuritis which is manifested by pain, hyperesthesia, formication, and numbness. Trophic disturbances such as loss of the nails of the hand are frequent. The dotted line on the cadaver in Fig. 2879 shows the course of a Mauser bullet which injured an officer at the battle of Santiago. The bullet entered the left side of the neck at about the level of the upper border of the thyroid cartilage, internal to the sternocleidomastoid. It ranged downward, backward, and to the right, making its exit one inch to the right of the seventh cervical spine. The officer dropped at once heavily to the ground from the momentary shock of the bullet's energy exerted against the spinal cord. A sergeant who was near thought him dead. He, however, regained consciousness very shortly and the author examined him the next day. The neck and left arm were swollen, and there was a burning pain in the distribution of the median nerve. We again examined this officer a few months after the injury and, off and on, for four years thereafter. He was at no time free from hyperesthesia, formication, neuralgic pains, and numbness which were principally referred to the left hand.

Wounds of the Air Passages.—Wounds of the larynx and trachea were very fatal with the use of the old armament, so much so that Chenu gives but one case of recovery in the Crimean War, and that was complicated by a fistula. In the Civil War Otis' statistics show that only seventy-seven cases of injury to the larynx and trachea reached hospital care out of 4,895 neck wounds, and the mortality in the seventy-seven cases was fifty per cent.

The beneficence which has come from the use of reduced caliber bullets is specially shown in recent wars. Follenfant[7] reports thirty-three cases in the Manchurian Campaign with three deaths. A number of observers in the same campaign testify to similar results.

Asphyxia from hemorrhage in the larynx is the greatest source of danger in wounds of the air passages. Later, pneumonia and edema glottidis sometimes appear. Among the sequelæ stricture of the larynx or trachea has been noted. The following case from the Spanish-American War is of special interest: Private Jacob H. M. Co. A, 4th U. S. Infantry, was shot by a Mauser bullet before Santiago, July 2, while he was lying down. "The bullet entered right temple two and one-half inches above and one inch posterior to the right canthus. It passed through the superior maxilla downward and backward, cut[8] through the posterior portion of the soft palate and entered the neck. Here it became deflected, probably by the thyroid bone, and entered the thyroid cartilage, thoroughly comminuting it, cutting into the esophagus wall where, being spent, it dropped into the stomach." The patient states that he subsequently passed the bullet per rectum. The immediate symptoms were profuse hemorrhage from the mouth

Fig. 2880. Photograph of Jacob H. M., March 4, 1911, at which time he was still wearing tracheotomy tube.

and nose, with difficult breathing and dysphasia later. The former was so marked that tracheotomy was necessary August 3. He was wearing the tracheotomy tube when last examined. The larynx is completely obstructed. The laryngoscopic appearances are cited in Coctor Mayer's article[8] above quoted (Fig. 2880).

Treatment.—Slight wounds of the front segment of

the trachea are best treated by suture if the respiratory efforts will permit. Dyspnea calls for immediate tracheotomy. Hemorrhage from the large vessels calls for ligature. Wounds of the esophagus should be sutured when this is practicable, care being taken to provide drainage at the bottom of the wound. When suture of the esophagus cannot or has not been done, feeding should be conducted through an esophageal tube or catheter passed through the mouth or nose into the stomach.

Wounds of the Spine.—Gunshot wounds of the spine are among the most fatal of the war wounds the bearers of which live to reach hospital care. Otis gives a mortality of 55.5 per cent. out of 642 gunshots of the spine in our Civil War, and he shows that the fatality increases with the proximity of the injury to the head:

Cervical spine	70	per cent.
Dorsal spine	63	per cent.
Lumbar spine	45.5	per cent.

In the Anglo-Boer War Stevenson gives the following mortality in forty-eight cases the majority of which were inflicted by reduced caliber bullets:

Cervical spine (5 cases)	60	per cent.
Dorsal spine (41 cases)	60.9	per cent.
Lumbar spine	00	per cent.

In thirty-six cases from the Spanish-American War and Philippine Insurrection (as a result of wounds by the new armament in the majority of cases) the aggregate mortality was seventy-five per cent.

We have nothing to offer in the way of statistics from the great Manchurian War but the reports from individual observers confirm the belief of the English and American surgeons on the high mortality of these war wounds notwithstanding the use of modern methods of treatment. It is generally admitted that fracture of the neural arch and direct lesion of the cord by either spicules of bone or the projectile proper are attended by a very high mortality. It was this class of cases that swelled our mortality to seventy-five per cent. in the Spanish-American War, and Stevenson fixes the mortality of the English in South Africa for similar lesions at seventy-eight per cent.

The spine is wounded more often under modern conditions, and this fact will add to the increasing deadliness of modern wars. The older, slow moving projectiles, having less penetration often lodged against the more resistant structures of the spinal column and actual lesion of the cord which is so fatal was often avoided. The steel clad bullets in present use penetrate all tissues very readily and the opportunity for fracture or perforation of the spine has been very much increased. Thus in the Civil War the relative frequency of spinal wounds was 0.26 per cent., in the Spanish-American War 0.55 per cent., and in the Philippine Insurrection 0.82 per cent.

Lesions of the cord of a grave nature are prone to occur with the use of high velocity projectiles when no direct violence by primary or secondary projectiles is apparent. Such cases, although appreciated in a vague way by older writers under the term concussion, were never fully understood until described by Mr. Makins following his experience in the Anglo-Boer War. He describes these particular lesions of the cord under the following terms: (1) slight concussion; (2) severe concussion; (3) contusion; (4) hemorrhage; (5) intramedullary hemorrhage (hematomyelia). He shows that any of these lesions may be caused by the vibratory force which is communicated to the cord when a bullet traverses the bony tissues which surround it.

1. *Slight concussion* is attended with few symptoms; there is no fatality, and the condition is likened to the spinal concussion noted in civil practice from shock or sudden jars, such as occurs in railway accidents.

2. *Severe concussion* exhibits parenchymatous hemorrhage in many cases, which in turn may show symptoms of partial or complete transverse lesion as a result of disorganization of tissue by the vibratory force of the bullet, which is liberated as the latter traverses the bony structures of the spine. The normal channels of communication with the higher centers are completely cut off as if they had resulted from contusion by direct violence.

3. *Contusion.*—Mr. Makins admits that the two conditions, concussion and contusion, are closely allied, but in the latter, at postmortem, there is adhesion between the dura and cord opposite the area of impact of the bullet in the bony framework.

Fig. 2881.—Appearance of Spinal Cord Enclosed in Membranes after Removal from the Canal. When the membranes were opened a white custard-like substance took place of the cord. Slight evidence of extradural hemorrhage existed. (Makins.)

The absence of direct lesion of the cord from fracture or otherwise suggests lesions by contre-coup. The cases are as fatal as those by direct injury. The amount of lesion generally corresponds to one or two segments. When held up the membranes opposite the affected portion are prone to collapse as shown in Fig. 2881. The case to which the figure refers is described as follows: "Total transverse lesion; slight intradural hemorrhage. Wound of entry (Mauser), below spine of scapula, close to right axilla; exit, two and one-half inches to left of tenth dorsal spinous process. Complete motor and sensory paralysis below ensiform cartilage, with well-marked hyperesthetic zone around trunk. All reflexes absent. Retention of urine. Incontinence of feces. Bedsores in sacral region developed during the first two days, and seventeen days later well-developed serpiginous trophic sores developed on the outer side of each leg and continued to increase slowly until death. The paralysis remained of the absolutely flaccid variety. Great emaciation occurred, accompanied by hectic fever, the temperature ranging from normal to 102.5°. During the third week double pleurisy developed. Postmortem no bone injury could be detected. The cord and dura mater were adherent over an area corresponding from the fifth to the eight dorsal vertebræ, and opposite the seventh the cord was soft and of the consistence of butter. A small intradural hemorrhage was still evident below the main lesion, not extensive enough to give rise to serious compression. General adhesions in each pleura. Cystitis."

4. *Hemorrhage.*—This lesion is both intra- and extra-

dural. The more frequent kind is described under the next heading.

5. *Intramedullary Hemorrhage* (Hematomyelia).—This form of hemorrhage is believed to be a constant accompaniment of nearly all grave transverse lesions not the result of direct traumata. Mr. Makin's experience convinces him that the large majority of cases of transverse lesion of the cord are the result of vibratory force. He saw but one case of pressure from a projectile and none from displaced bone fragments. In a typical case of severe concussion of the cord from gunshot the lateral transmission of energy through the bony framework and cerebrospinal fluid is so violent that there is rupture of the substance of the cord with resulting parenchymatous hemorrhage and the appearance of symptoms which mark a transverse lesion as definite as that which follows direct trauma.

The vibratory force is not alone common to the high power military rifle. It is noted in lesions from certain revolvers and automatic pistols which are fast supplanting the use of old time weapons in civil communities. The effects of vibratory force on the spinal cord from these more efficient weapons have already been pointed out by Doctor Rudolph Winslow[11] of Baltimore in cases of his own and in the practice of others in which serious and fatal transverse lesions of the cord without direct impact have occurred from pistol bullets.

Our own experience in the Santiago Campaign has convinced us of the frequency of cord lesions from the lateral transmission of the reduced caliber bullet's energy. The cases of partial lesion which ended in recovery become especially convincing when we study their clinical history. One of the most interesting cases is that of First Lieutenant A. S. 13th U. S. Infantry the records of whose case we have obtained from the register of the Hospital Ship *Relief* and other sources. "On July 1 while standing with his company at the foot of a hill during the advance on Santiago, received a wound in the neck probably from a Mauser bullet. The bullet entered on the right side just below the inferior maxillary bone, one inch in front of the angle of the jaw. The wound of entrance was a clean-cut hole the size of a lead pencil. The course of the bullet was backward and slightly downward, emerging at the back of the neck on a level with and to the left of the fifth cervical vertebra. At the time of the injury he felt no pain at the site of the wound but says that the sensation was as if he had been grasped by the wrists and thrown violently to the ground. The wound of exit is similar to the wound of entrance. There was very slight hemorrhage. A few minutes after receiving the injury he was carried from the firing line by members of his company, and removed to the first Division Hospital; during this time he was conscious of his wound for the first time. Was kept there for ten days and then removed in an ambulance seven miles over a bad road to the third Division Hospital at Siboney."

We examined him July 10, and found his condition very much as described by the surgeon on the *Relief* the following day, which reads as follows: "Patient was voiceless and making constant efforts to clear his bronchial tubes of accumulated mucus. Complete paralysis of right arm and leg and partial loss of power of left arm and leg. Grip of left hand very feeble. Respiration normal but an almost constant spasmodic cough. Has lost control of sphincters and has involuntary passages from both bladder and bowels. In a very exhausted condition and has profuse diaphoresis. Complains of pains all over body. Ordered a hypodermic of morphine, gr. ¼ and atropine gr. 1/150.

"July 14.—Radiograph taken by Dr. Gray shows an injury of one of the cervical vertebræ, probably the fifth. Injury seems to be to the left side of the body of the bone. Has received no treatment other than complete rest and a nightly hypodermic as noted above, which gives a good night's sleep and markedly reduces the sweating. Has regained control of the sphincters and is able to use bed pan and urinal.

"July 19.—During the past six days there has been a decided improvement in the general condition of the patient. He is brighter in appearance, he can articulate more distinctly and there is a decided return of power in the right leg. The right hand is still absolutely powerless but the grip of the left hand is stronger. Appetite is good and bowels require to be moved with enemas. Unable to sleep without morphine but the atropine has been discontinued. Circulation apparently unimpaired.

"July 21.—Improvement in general condition still continues. The external wounds have healed so well that they are not noticeable except on close inspection. The hypodermics have been discontinued and trional and sulphonal substituted.

"July 22.—Transferred from hospital ship *Relief* to hospital, Fort Porter, N. Y." The subsequent history of the case shows a gradual restoration of function of arms, legs, and sphincters. This officer had recovered sufficiently in the course of a year to be detailed as instructor in one of our military schools. He was later retired from active service and died January, 1906, seven and one-half years after the injury, cause not stated. We have every reason to believe that the lesion in this case was due to vibratory concussion of the cord as described by Mr. Makins.

Symptoms.—The symptoms of gunshot of the spine may be divided into those having lesion of the vertebræ without and with cord involvement.

Symptoms without cord involvement.—Such a lesion was more frequent in the days of the old armament, when projectiles had less power to penetrate and fracture bone. They are equally rare under modern conditions if the modern rifle bullet traverses the center at any distance except the proximal ranges. The higher velocities against either center or neural arches by the old or new armament are apt to show lesion with cord involvement. Angular deformity which is such an aid in the diagnosis of spinal injuries in civil practice is not so often seen in gunshot injuries, and this is especially true of injuries by the new armament where the bullet causes so little displacement of fragments, except at proximal ranges.

Symptoms with cord involvement.—The symptoms will be similar to those from fracture dislocation in civil hospitals from causes other than gunshot. There is usually more or less shock and complete paralysis below the seat of injury which corresponds to the region involved. When the dorsal region is implicated, paraplegia occurs. Lesion of the cervical region will be followed by paralysis of the upper and lower extremities. In partial lesions the paralysis may show itself in part of a member or it may extend to one or more members. The type of paralysis will vary with the injury and the location thereof. The sensory symptoms are hyperesthesia, anesthesia, numbness, formication, and a sensation of pricking with pins and needles. At times all pain is absent. Numbness and ensuing tingling and pain to touch in a case of complete loss of sensation are regarded as symptoms of prognostic value. The girdle sensation is present in severe cases, and the thermic sense is sometimes lost or diminished although the sense of touch still persists. Permanent anesthesia is unfavorable to ultimate recovery. Knee-jerk is diminished or absent in lesion of the lumbar region; impairment or absence of the cremasteric, plantar, and other reflexes points to lesion of certain parts of the cord whence these reflexes emanate.

Retention of urine is the most frequent of the genito-urinary symptoms. Incontinence from over-

flow next appears, and cystitis comes on still later as a result of catheterization. Later still vesical calculi appear from the deposits in an alkaline urine. Certain injuries of the cervical region are often followed by annoying priapism.

Among trophic symptoms herpes zoster, dry skin, loss of nails, and decubitus are noted. The latter is more often seen over the buttocks, heels, and external malleoli. The temperature rises early in some cases and it is apt to register as high as 108° F. in cervical lesions. Septic fever from bed sores and slough from unavoidable infection generally hasten the end.

Of the digestive symptoms distention of the intestines by gas is the most important and serious because of the impediment which it offers to respiration. Constipation is frequent, and incontinence is noted in the later stages.

The pulse is generally full with a tendency to intermit. Paralysis of the muscles of respiration brings on difficulty in relieving the accumulation of mucus in the larynx and trachea. Later edema and congestion of the lungs are apt to supervene and they are fruitful causes of death. Contracted pupil is seen in injury to any part of the cord and when the cervical sympathetic is implicated narrowing of the palpebral fissure of the side involved generally appears.

Diagnosis.—The diagnosis of spinal cord injury will depend upon the symptoms already noted, and *x*-ray evidence when pressure is present on the cord from depressed bone or a lodged missile.

Prognosis.—The prognosis is difficult. Pressure from a lodged bullet is not necessarily fatal provided the symptoms of transverse lesion are but partial and secondary changes remain absent. Pressure from displaced bone is unfavorable in proportion to the violence suffered by the cord as a result of the bullet's vibratory force. Slight degrees of medullary hemorrhage (hematomyelia) will generally cause partial symptoms of transverse lesion, and this may be followed by remote but incomplete paralyses. Meningeal hemorrhage when uncomplicated by inflammation is not fatal. The greatest uncertainty in prognosis exists in cases of concussion with hematomyelia, and in such cases the prognosis becomes favorable as the secondary changes are delayed.

Treatment.—After the primary dressing, the patient should remain quiet on a fracture bed. Transport should be avoided whenever the environments will permit. Care should be employed to prevent pressure bed sores, and when the latter are of trophic origin every effort should be made to keep them clean and free from sepsis.

Operative treatment can avail nothing except in cases of pressure from the bullet or spicules of bone as these may be revealed by *x*-ray evidence. As already stated the large majority of cases of transverse lesions, complete or incomplete, that reach hospital care are the result of concussion from the vibratory force of high velocity bullets for which a formal laminectomy is never indicated. Military practice in this regard assumes a wide departure from the practice of civil hospitals where laminectomy is often attended by brilliant results for the removal of pressure in fracture dislocations.

Wounds of the Chest.—Two changes of importance have come about in gunshot wounds of the chest under modern conditions: (1) the number of chest wounds is greater when men fight lying down during which the upper part of the body alone is exposed to fire, and (2) the mortality from gunshots of the chest is much less from the use of the modern rifle bullet. In the Civil War the hospital mortality was 27.8 per cent., and it was but 9.5 per cent. in the Spanish-American War. The mortality in the Anglo-Boer and Russo-Japanese Wars was correspondingly less. The only exception was noted in the Turko-Balkan War on the side of the allied armies when soldiers were wounded by the pointed or spitz bullet of the Turks. As stated already, the deadliness of the pointed bullet is great in all body wounds, and the beneficence so happily noted after the use of the ogival-headed bullet in chest wounds will disappear as the armies of the world continue to adopt the more perfect projectile.

Wounds of the chest are divided into non-penetrating and penetrating.

Non-penetrating wounds include contusions and lacerated or penetrating wounds of the skin without penetration of the pleural cavity. Contusions of the chest pure and simple, are of no moment, and require no special comment. When inflicted by large projectiles or from smaller projectiles animated by sufficient violence contusions are at times complicated by internal injuries which have resulted in hemoptysis, pneumothorax, hemothorax, emphysema, pleuritis, or pneumonia. Contusion with pain should be immobilized by strapping and when the last-named complications appear they should be treated in the ordinary way.

Lacerations and penetration of the skin are attended with no mortality under modern conditions of treatment. In preantiseptic times, the mortality in 11,549 cases recorded by Otis, never exceeded one per cent. Lacerated wounds of the chest are apt to heal slowly on account of the movements of the chest wall; they are generally infected and they require prompt and thorough antiseptic treatment at the first dressing.

Penetrating wounds of the chest by the old armament caused a death rate of 62.5 per cent. out of 8,715 cases noted by Otis. The French lost 91.6 per cent. of their cases in the Crimea, while the mortality of the English troops was 79.2 per cent. in the same campaign. These high mortalities will no longer obtain under modern conditions. The small frontage of the reduced caliber bullet, at the ordinary battle ranges, causes slit-like wounds in lung tissue that are prone to heal readily. In the Spanish-American War and Philippine Insurrection out of 283 cases by different kinds of missiles our mortality was 27.5 per cent., while the English lost but fourteen per cent. out of 214 cases in the Anglo-Boer war. In campaigns likely to enforce immediate transport, and attended with privations and unfavorable conditions of weather, the mortality under modern conditions will necessarily be high. When the conditions are altogether favorable with fixed hospitals in the immediate vicinity of battle fields, the mortality is very much reduced. In some of Follenfants statistics the mortality in the Russo-Japanese war fell as low as 3.67 per cent.

Symptoms and Complications.—In some cases which we saw at Santiago there were no symptoms and it was difficult to restrain the wounded who seemed to regard their injuries as trivial.

Shock is present in only a certain percentage of the cases, and it generally accompanies cases with more or less extensive trauma to the chest wall. Pain is apt to be severe when the pleura is badly lacerated and fracture of the ribs is present, but in the ordinary uncomplicated cases pain is often absent. Hemoptysis which lasts three or four days occurs in about seventy-five per cent. of the cases. Cough is generally noted and of short duration. Hemothorax appears in all cases of pleural injury, and when it occurs in sufficient amount to become a clinical factor it is usually noted on the second or third day. There is a rise of temperature from absorption of fibrin, a rapid pulse, cyanosis, more or less dyspnea, and restlessness, while the remaining symptoms are those common to the presence of fluid in the pleural cavity. Pneumonia which was more or less common after wounds by the larger calibers, is seldom noted after wounds by small jacketed bullets. Empyema is infrequent after wounds by reduced caliber bullets. The chances of infection from infected clothing carried in the wound are much less. Pleurisy, abscess of the lung, and pneumonia

are complications associated with primary infection and their occurrence is proportional to the amount of lesion and the sectional area of the projectile. Abscess is specially apt to occur with lodged missiles, spicules of bone, or pieces of clothing.

Treatment.—After the application of a clean dressing the patient should be put to bed with shoulders elevated to insure comfort. Transport should be delayed until danger of complications has passed or until the wounds have healed. Forty-six per cent. of a group of twenty-six cases noted by Greenleaf in the Spanish-American War suffered from hemothorax during transport and fifty per cent. of the latter were further complicated by the occurrence of empyema. Chest cases should be treated in the first aid zone whenever practicable. The majority of cases of hemothorax are slight and require no treatment other than rest in bed. When the amount of blood embarrasses respiration aspiration is in order. When practicable this should be delayed to a time when injured vessels have had sufficient time to heal lest coagula are disturbed with the recurrence of hemorrhage.

The source of hemorrhage is generally from the intercostals or mammary arteries. When it is not practicable to ligate the bleeding vessels, pressure by Desault's method should be practised. This is accomplished by pressing the center of a square piece of gauze in the wound with the finger and subsequently packing the pocket thus made with loose gauze. The corners of the gauze originally pressed in by the finger are pulled upon to make pressure on the internal surface of the wound next to the sternum or ribs.

When large quantities of clotted blood fail to be absorbed or infection sets in, free incision and resection of part of one or more ribs should be practised, followed by thorough irrigation.

In the case of fractured ribs it may be necessary to explore the wound for spicula of bone. Gunshot wounds of the costal cartilages, sternum, and scapula generally show clean-cut perforations or guttering, and this is specially true of wounds from the reduced caliber bullets. Fracture of the clavicle is attended with comminution from the nature of its compact substance.

In all injuries of the bony framework of the chest wall immobilization should be practised after the application of the first aid dressing.

Lodgment of Bullets in the Chest.—Projectiles imbedded in lung tissue or against the spinal column should not be disturbed. When lodged in the chest wall no attempt at removal should be made until the location of the foreign body has been ascertained by *x*-ray evidence, and it should not be removed then unless it causes annoying symptoms. The dangers of setting up sepsis in the pleural cavity while attempting the removal of lodged missiles in the chest wall should be borne in mind and the greatest precautions should be employed in the surgeon's technique. Missiles that are easily accessible under the skin should be removed as soon as the surgeon can master the environments.

Wounds of the Heart and Pericardium.—When a gunshot wound of the heart takes place death occurs at once in nearly every case. Some of the observers in recent campaigns have reported unmistakable cases of recovery in men who were shot in the cardiac area, and their recovery has been ascribed to the way in which the heart and great vessels are held together by loose areolar tissue which favors a certain amount of displacement at the moment of impact by a bullet impressed with a low remaining velocity. Again, the variability in the size of the organ from diastole to systole has been advanced as one of the causes of escape from fatal injury. It is well known that incised wounds have been inflicted on the heart without fatal results, and since the slit-like wounds of reduced caliber bullets take the nature of incised wounds at times, there seems to be no good reason why recovery from bullet wounds by the modern military rifle should either be improbable or impossible. Manteuffle and Butz from the Russo-Japanese War report eight cases altogether in which the wounds of aperture on the surface of the body made it difficult to believe that the heart had escaped injury.

Symptoms.—Wounds of the heart and pericardium exhibit great distress, shock, irregular action of the heart, syncope, and severe pain in the cardiac area. If hemopericardium occurs it comes on some days after the receipt of the injury. The fluid at first flows from the pericardial wound into the surrounding tissues or the pleural cavity. Later the pericardial wound becomes closed by coagula and accumulation of blood occurs in the pericardium with the symptoms already noted. There are also increase of the cardiac area, loss of apex beat, and friction sounds from the inner lining of the pericardium rubbing against the coagulated blood. If pericarditis sets in, elevation of temperature occurs.

Treatment.—If symptoms of fluid in the pericardium become urgent paracentesis of the pericardium should be preformed. If pus is present it is best removed by incision and drainage.

Wounds of the Abdomen.—Gunshot wounds of of the abdomen are usually discussed under the following classification: (1) Contusions. (2) Non-penetrating flesh wounds. (3) Penetrating wounds of the abdominal cavity. (4) Penetrating wounds of the abdomen.

1. *Contusions of the abdomen* may be simple or they may be complicated by visceral injury. In the first instance the condition is rare and does not differ from like injuries from other traumata. Contusions complicating visceral injury, always rare, are not referred to by Mr. Makins in his "Surgical Experiences in South Africa." Otis reports but forty-one cases from our great Civil War. The cases are supposed to occur from impact against the abdominal wall by spent balls. The earlier symptoms are shock, pain, vomiting, and rigidity of the abdominal wall, while later symptoms point to hemorrhage or peritonitis. Persistence of the symptoms is more significant than their severity when considered in the light of subsequent treatment. Rapid pulse, persistent vomiting, and increasing rigidity of the abdominal wall point to unmistakable peritonitis.

Treatment.—All cases of contusion of the abdomen should be placed in bed with shoulders elevated and knees drawn up to relax the abdominal walls. What seem to be simple cases are at times complicated by serious internal rupture. If the symptoms of shock, pain, and vomiting persist, or if the physical signs indicate the accumulation of blood in the abdominal cavity, an exploratory laparotomy should be undertaken at once. Without prompt operative interference such cases are known to be very fatal, and for this reason the surgeon is not justified in delaying operation for more favorable environments.

(2) *Non-penetrating Wounds of the Abdomen.*—In this class, happily, there is no mortality when the cases are treated in accordance with modern methods. There is often great difficulty in arriving at an exact diagnosis, and this is especially the case in the thicker portions of the lower part of the abdominal and pelvic walls. Wounds of the colon and sigmoid flexure often give no symptoms of penetration and this adds to the difficulty in diagnosis. Non-penetrating wounds of the abdominal wall are treated on the principles laid down for infected wounds. Cases in which the projectile has traveled some distance under the skin should be drained at different points, or the channel may be laid open from the point of entrance to that of exit, and treated as an open wound.

(3) *Penetrating Wounds of the Abdominal Cavity.*—In this class we include those wounds in which there is no wound of either the omentum or mesentery, or of

other viscera. It is difficult to conceive how a projectile can traverse the abdominal cavity without inflicting perforation on either the hollow or solid viscera, and yet the literature of gunshots of the abdomen gives undoubted instances of the kind both before and since the change in the armament. The reports from recent wars testify to increasing frequency of penetrating wounds of the abdomen from the use of reduced caliber rifles, and these are no doubt, in part at least, the kind of cases that have occurred at times and which have puzzled military surgeons by their miraculous recoveries. At Santiago we saw men recover from abdominal wounds by the Spanish Mauser bullet when the track of the bullet, as judged by the location of the surface wounds, made it apparently impossible for the bullet to have travelled outside the intestinal area. The patients got well without evidence of either local or general peritonitis, much to the surprise of the surgeons who saw them.

Fig. 2882.—Shows Omentum Covering Lesion in Wound of Mesentery in Thornburg Case.

One of the most indubitable instances of gunshot penetration of the abdomen which goes far to support the contention that the movable intestine is capable of being pushed aside to avoid perforation occurred in the practice of Major R. W. Thornburg, U. S. A., as follows: "Private William U., Co. 'H,' 30th U. S. Infantry, recently entered Latterman General Hospital, San Francisco, Cal., for gunshot wound of the abdomen self inflicted. The weapon used was the U. S. Army reduced-caliber magazine rifle loaded with a full-charge cartridge. Wound entrance three by two centimeters diameter, located five centimeters to left and two centimeters above the umbilicus. Wound of exit one centimeter in diameter, located directly above the left posterior superior iliac spine, on a level with the umbilicus. There were fifteen wounds of ileum, three of descending colon, numerous wounds of mesentery. No complete intestinal perforation was discovered. Twelve ruptured blood-vessels were found. The intestinal wounds consisted of destruction of the peritoneum and muscular coats. The wounds of the viscera were principally due to the explosive effect of the cone of fire proceeding base forward. The muzzle of the rifle was placed against the body, and an olive drab woolen shirt and cotton undershirt were perforated by the bullet.

"When received at hospital patient was so much shocked that the surgeons refrained from doing a resection of the wounded intestine. The wounds of the colon were inverted, blood-vessels tied, and the wounded ileum and mesentery were covered by omentum as shown in Fig. 2882. Fig. 2883 shows the protruding gut and a piece of omentum. Fig. 2884 depicts the character of the lesion of the denuded and lacerated intestine. The peritoneal cavity was drained front and rear and the patient was placed in Fowler's position with Murphy drip for twenty-four hours. There was at no time any infection and a perfectly normal convalescence and recovery were the result."

It is difficult to conceive how the ball and the explosive charge could have traversed the abdominal cavity as indicated in the history of this case without perforating the intestinal tube except upon the theory of displacement by the pressure which was exerted upon the tissues in all directions.

(4) *Perforating Wounds of the Abdomen.*—In this class the peritoneum is opened and in addition there is lesion of some of the contained viscera.

Pathology.—The wound of entrance is most generally met with on the anterior surface of the body, although from high-power military rifles a projectile may enter the peritoneum from a distant anatomical part, such as the thorax, neck, or buttock.

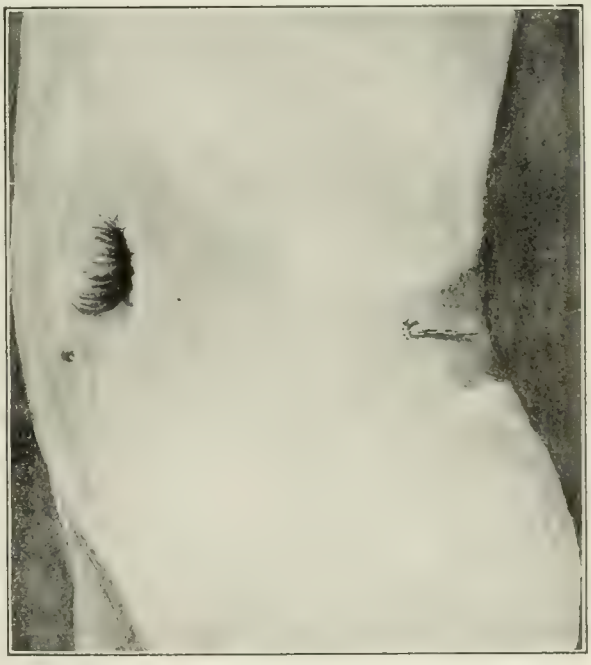


Fig. 2883.—Knuckle of Gut from Wound of Entrance and Omentum from Wound of Exit in Thornburg Case.

Protusion of the omentum or intestine at the external wound occurs at times in wounds by fragments of shell, the larger caliber military rifles, or proximal shots from present-day military rifles.

Bullets impressed by high velocity travel in a straight line and the probability of injury to contained viscera must be based on the location of the external wounds and a straight line drawn between these. The amount of destructive effects depends upon the angle of impact against the viscera. In the case of the intestines, wounds transverse to the gut have less destructive area than those disposed obliquely. In smaller perforations of the small intestines hernia of the mucosa occurs on account of the latter's redundance over the serous coat, and this pathological condition has figured extensively as a possible explanation of unexpected recoveries in abdominal wounds by reduced caliber bullets in recent campaigns. Hernia of the mucosa is not observed in wounds of the stomach or large gut.

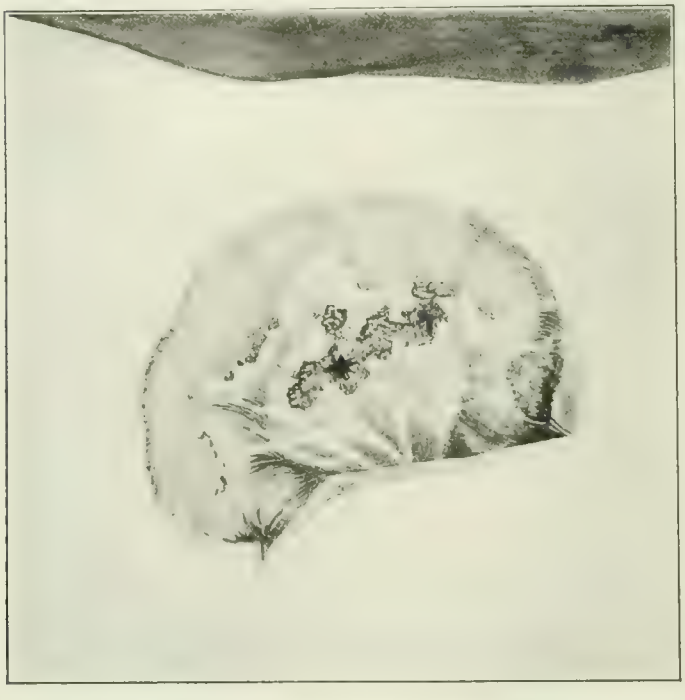


Fig. 2884.—Shows the Denuded and Lacerated Intestine in Thornburg Case.

The amount of destructive effects is farther conditioned by the sectional area of the projectile, the velocity, and resistance on impact. Water and bone offer the greatest amount of resistance on impact, so that in a loaded intestine containing a fluid mass, the lesion will be much greater than it would be on an empty organ at the same range by a like caliber projectile.

Hemorrhage is common in wounds of the mesenteric border, the omentum, and solid viscera. It is one of the potent causes of death in abdominal wounds, where the blood-vessels lie unsupported.

Extravasation from hollow viscera, like the stomach, urinary bladder, and gall-bladder, has an important pathological bearing. A wound of the stomach, unless the contents of the organ are entirely fluid at the time, is accompanied by partial extravasation, only when the wound is sufficiently large. Wounds of the urinary bladder and gall-bladder are generally followed by extravasation of their entire contents.

Wounds of the intestines are more apt to exhibit extravasation when manipulated. In the first twenty-four hours eversion of the mucosa and absence of peristalsis aid in arresting extravasation. At the end of this time if the peristalsis is resumed the mucous membrane retracts and when the exudate is insufficient, extravasation is apt to occur.

A cut vessel at the mesenteric border threatens life by hemorrhage at once, or the occurrence of gangrene of the intestinal area of the gut involved.

In the presence of a gunshot wound of the abdomen it is well to remember that the outcome is uncertain; the exact lesion is problematical; all penetrating and perforating gunshot wounds of the abdomen are infected; the complications that are apt to occur are uncertain; and further, it is estimated that in all peritoneal wounds, the viscera have been perforated in nearly every instance. As many as twenty-eight perforations have been recorded in one case. Perforations of the intestines occur in shots disposed from flank to flank, transversely or obliquely.

The development of perforation peritonitis in intestinal wounds is the rule in twelve to twenty-four hours. Virulent infections have been known to cause death before the onset of the characteristic symptoms indicating the appearance of peritonitis. In any case of gunshot of the abdominal cavity the outcome will depend upon the nature of the lesion, the amount of hemorrhage, the kind of infection, and the presence of extravasation from hollow viscera. Effused blood may be walled off and absorbed when it occurs in small quantities. Larger quantities are apt to undergo septic changes ending in peritonitis.

General Symptoms.—Constitutional shock, although generally present, may be absent, a fact which lessens its diagnostic features, but the duration of shock adds to its importance as a symptom.

Pain is a fairly constant symptom. Meyer and Parker of New Orleans have described it as a griping pain at first, about the region of the umbilicus in lesion of the small intestines. Later the pain is distributed to the groins, chest, and over the abdomen generally.

Tympany is a common symptom of perforation only in the later stages. Some observers claim that it is an early and frequent symptom from wounds with larger calibers due to extravasation of gas in the general peritoneal cavity.

Among the positive signs of perforation we may mention escape of intestinal gas, feces, or intestinal worms from either of the external wounds protrusion of the injured gut at the wound of entrance or exit, and passage of the missile or blood by the anus. Passage of red blood from the anus points to wound of the colon or rectum. Dark bloody stools indicate lesion of the small intestine.

Diagnosis of perforation is often uncertain and it can only be inferred from the location of the wounds of entrance and exit. Wounds in the umbilical region are apt to be attended with lesion of the small intestines; wounds running from flank to flank are apt to include lesion of the colon; wounds located above the umbilicus and below the costal margin are more often attended with lesion of the transverse colon and stomach.

Prognosis.—The fatality of perforating gunshot wounds of the abdomen largely depends upon the amount of destructive effects in the tissue involved, and the latter is constantly dependent upon the factors of velocity, sectional area of the projectile, and the resistance encountered on impact. In the days of the old armament the mortality averaged about ninety-five per cent. Out of 115 cases in the Spanish-

American War and Philippine Insurrection treated under modern conditions the mortality was 67.1 per cent. We have no exact data on the mortality in the Russo-Japanese War, but the reports of individual reporters bring the mortality as low as fifty-six per cent., which is based no doubt on a restricted class. We believe that our own mortality of 67.1 per cent. is a fair average of the mortality which is encountered in the wars of the present. The wounds in the large majority of our cases were inflicted by reduced-caliber bullets, with ogival heads. The reports from the Turko-Balkan War indicate that the pointed bullet of the Turkish army, which corresponds to that recently adopted by the United States and British armies, was very fatal for all body wounds and especially those of the abdomen. But few of the wounded are said to have lived long enough to reach hospital care. This, as we have already pointed out, is no doubt due to the unstable action of the pointed bullet. Its center of gravity is located at its base, and the least resistance on the bullet's point causes it to turn side on. Its sectional area is thereby increased, and as it travels at great velocity the amount of destruction which it inflicts is correspondingly great.

The prognosis in gunshot wounds in civil hospitals corresponds largely to the factors of sectional area, velocity of the projectile, and resistance on impact. In olden times the abdominal wounds of the large dueling pistols were all fatal. Later, it became the vogue to use small pocket pistols, and the destructive effects of the lighter and smaller bullets inflicted wounds with limited lesions that often recovered under the quieting treatment of opium and rest in bed. Later still, the pistols and revolvers used in civil life were made more efficient, the use of smokeless powders has added to the velocity of the projectiles to such an extent that the steel-jacketed bullets of the automatic pistols now have an initial velocity as high as 1,400 feet seconds. Such a velocity of a short bullet like those of this class of hand weapons causes it to turn side on, when impact is made against any kind of resistance in the body, and the resulting lesion exhibits much more destruction of tissue than formerly. Recovery under the quieting effects of opium seldom occurs, and the shock, hemorrhage, and greater extent of the lesion complicate the surgeon's efforts at operative interference. The results of Richardson, in Charity hospital, New Orleans, before operative treatment was employed, in the five years preceding 1887, as pointed out by Professor Rudolph Matas[1], gave a mortality of 59.4 per cent. In a series of statistics which may be found in the work referred to, Matas and his assistants have clearly shown that operated and non-operated cases give but little if any advantage in favor of the operative method in the last twenty-five years. We believe Richardson's statistics deal largely with lesions by the smaller calibers and more imperfect weapons of that day, and that the lesions were more amenable to any kind of treatment than the wounds which were inflicted by larger calibers and more perfect weapons later and up to the present. Matas informs us that the operative treatment is gradually losing favor in Charity hospital, because the results are no better than they are by the non-operative method. The character of gunshot wounds of the abdomen in both civil and military practice has undergone recent changes for the worse, and that is due to the use of short unstable bullets upon which high velocities are impressed by the nitrocellulose compounds. The deadliness of the pointed bullet of the Turkish army in the Turko-Balkan War has already been referred to and since this bullet is destined to supplant the use of the better balanced ogival headed bullets of a decade ago, fatality in abdominal wounds under any plan of treatment, will continue to be great.

Treatment.—In any case of gunshot of the abdomen the first and most important consideration is the advisability of opening the abdomen.

Contraindications to Operation.—(1) Impending death from collapse or increasing shock contraindicates operation.

(2) When twelve hours have elapsed since the injury and peritonitis has set in, there is little hope of recovery from surgical aid.

(3) The chances of recovery are materially lessened by unfavorable surroundings and the inexperience of the surgeon and his assistants.

(4) Operation for gunshot of the ascending or descending colon is not as imperative as it is for injury which includes lesion of the small intestine, and in cases in which the entrance wound is to one side of the median line—nearer the flank, the course of the ball ranging anteroposteriorly—operation should be delayed. In intraperitoneal shots of the large gut by small calibers especially, the outcome without operation is generally favorable. The opening in the gut is in contact with the parietal peritoneum, the intestinal contents are solid, and the gut is immobile, all of which reduce the chances of extravasation.

(5) In military practice it often happens that cases of gunshot through the intestinal area are brought within the sphere of favorable environments long after the expiration of the first twelve hours. It is wise in all such cases to withhold operation if the patient is doing well. Such cases have exhibited a surprisingly large percentage of recoveries in recent campaigns. They sometimes require secondary laparotomies at a later period for abscess from localized peritonitis. This is no doubt the class in which the small-caliber bullet has made a wound in the intestine which has been subsequently closed by hernia of the mucosa as already explained, or in which the projectile has passed through the intestinal area without perforating the gut.

The consensus of opinion among military surgeons is against laparotomy in the field except in those cases already mentioned, in which hemorrhage is going on. The opportunity for early operation is seldom presented; the cases are first seen in the first-aid zone where the environments for such a painstaking operation are most forbidding from the lack of trained personnel, water, sterile dressings, proper shelter, equable temperature under canvas at all times of the year; and, furthermore, the difficulties that arise from wind, dust, and flies are often insurmountable. Again we may state that a comparatively small number of laparotomies, although the environments are favorable, require a corps of assistants whose services are intended for a far greater number of important wounds, that are threatening life on all sides, and justice to the greater number forbids the employment of this operating staff to administer to the wants of a comparatively few. Humanity and the best interests of the State command the relief corps to save the greater number by preference.

Indications for Operation.—In severe abdominal wounds in which there is protrusion of the gut, which is generally soiled by dirt and feces, operation should not be withheld for lack of proper environments. If internal hemorrhage is progressing as indicated by the symptoms, laparotomy is at once indicated regardless of the surrounding conditions. Within the first twelve hours, laparotomy is in order in all cases in which the bullet has crossed the intestinal area, provided the condition of the patient and the environments are fit. In expert hands, operation under such circumstances will not add to existing danger, and surgical skill will save more lives than a *laisser faire* policy.

Operation.—Having determined upon the necessity for abdominal section, as soon as the patient has been anesthetized, a median incision should be made in cases in which the ball has entered near the midline of the abdomen, or in which the track of the bullet has crossed a median plane. If the course of the ball is to

one side and the entrance wound is to the same side of the median line the incision may be made over this corresponding side. All bleeding in the abdominal cavity should be arrested by ligation or pressure with a gauze pad, and the extravasated blood removed by sponging. Intestinal perforations should be closed as they are met if small; when large they should be clamped with rubber-covered forceps to be attended to later. Drainage should be employed in cases of doubt. It is safer to drain than not to drain. Drainage should be employed where the remaining lesion may end in necrosis, and when it becomes necessary to arrest the bleeding by tamponade. Bleeding in abdominal wounds should never be controlled by the actual cautery.

Wounds of the Small Intestines.—The search for perforations should be commenced at the ileocecal junction, tracing the small gut rapidly upward, being careful to return each loop as soon as examined. Large perforations and lesions of the mesenteric border that call for resection should be controlled by clamps to be attended to later. Small perforations on the convex border are closed by double continued or purse-string sutures. Larger perforations should be closed by a double line of seromuscular sutures disposed with the short axis of the gut, the first to include all the coats, the second to include the seromuscular layer. In perforations which approximate half the lumen of the intestine, the sutures should run in a direction coincident with the length of the gut. When the lesion comprises more than half the lumen of the gut, a resection should be made. An injury to the mesenteric border of a half-inch or less may be closed by suture. If the area involved exceeds a half-inch, there is danger of gangrene, and the rule is to resect. Suturing should be made with fine silk threaded in a small round needle, employing six sutures to one inch. Resections are done by end-to-end approximation with the Czerny-Lembert suture. If the operator is inexperienced or where it is necessary to save time a Murphy button should be used. When the condition of the patient forbids, in the presence of multiple perforations, it is preferable to do one circular enterorrhaphy, rather than two or more resections even though several feet of gut are sacrificed. The closure of perforations in large intestines covered by peritoneum is similar to that in small intestines; resections in the former are seldom called for.

Cleansing the peritoneal cavity by irrigation is necessary only when extensive fouling is present. If irrigation is necessary it is better to flush the peritoneal cavity with hot saline solution.

Gunshot Wounds of the Stomach.—Wounds of the stomach are closed by Lembert sutures in the direction of the blood-vessels, and when the wound is large the Czerny-Lembert suture is preferable. To treat wounds of the posterior wall it is better to break through the gastrocolic omentum, and when the pancreas is injured posterior drainage through the skin of the lumbar region should be made.

Wounds of the Large Intestine.—Wounds of the large intestines like the cecum, ascending and descending colons, often recover without operation for reasons already stated. This is true of injuries by the old armament, and more so after gunshot by the reduced-caliber bullets. In forty cases in the Anglo-Boer War Stevenson fixes the mortality at 32.5 per cent., although some of the wounds were complicated by perforation of the liver, urinary bladder, and kidney. Wounds of the sigmoid flexure and rectum when uncomplicated by shots through the bladder, adjoining pelvic bones, or femur, also belong to the hopeful class. In the wounds of the sigmoid and rectum not covered by peritoneum the prime indication is drainage to ward off cellulitis, septicemia, and fistula which result from extravasation of feces in the tissues. A one-half inch tube should be introduced as far as the opening in the bowel, at the same time that sterile gauze is packed around the tube to prevent the intestinal contents from contaminating the sides of the wound.

Wounds of the Liver and Gall-bladder.—Uncomplicated gunshots of the liver require no surgical aid. If complicating wounds are suspected exploratory laparotomy is indicated. Hemorrhage from liver tissue is best controlled by gauze packing, the end of which is left protruding through the abdominal wall, and when necessary the edges of the wound are brought together by sutures with a straight blunt needle threaded with number three or four catgut. Small perforations of the gall-bladder are closed by silk sutures. If the loss of substance is extensive cholecystectomy should be practised.

Gunshot wounds of the pancreas are treated by the arrest of hemorrhage and lumbar drainage.

Wounds of the Spleen.—The surgical indication is control of hemorrhage, and when this cannot be accomplished, splenectomy should be resorted to.

Wounds of the Kidney.—Uncomplicated gunshots of the kidney by the modern military rifle bullet heal readily with no symptom beyond a transient hematuria. They are treated by rest in bed and the administration of opium. Uncomplicated gunshots of the kidney are rare. Wound of the pelvis demands nephrotomy for temporary drainage of urine. If hydronephrosis develops incision and drainage should be practised.

Wounds of the Urinary Bladder.—Laparotomy should be done in all cases of intraperitoneal wounds of the bladder when the environments permit. The urethra is first cleansed by a mild antiseptic solution. A catheter is next introduced as far as the bladder and secured in place for the purpose of distending the bladder later to bring the perforation into view if this is necessary. The perforation should be closed by a deep and superficial line of sutures. Drainage of the bladder is accomplished by urethral syphonage which should be maintained for seventy-two hours; or drainage may be accomplished by a perineal section when the difficulties of transport interfere with syphonage from a suprapubic drain.

Extraperitoneal wounds should be treated by keeping the bladder empty and by drainage through the external wound as described for extraperitoneal wounds of the sigmoid flexure and rectum.

Wounds of the External Genitals.—Wounds of this region form a small group; they were never considered dangerous in the days of the old armament, and they are less so now.

Wounds of the penis consist of lesion to the skin and erectile tissue. They are smaller than the caliber of the bullet. External hemorrhage is not frequent, but hematomata are common.

Wounds of the urethra are the most important injuries of the penis. Drainage is the principal indication in the treatment. The opening in the urethra should be located, and a soft catheter passed through it into the urethra as far as the bladder. If this cannot be readily accomplished a suprapubic incision or aspiration should be practised until the patency of the urethra has been established. In some cases perineal section may be preferable.

Wounds of the testicle are accompanied with more or less shock, vomiting, and pain radiating into the abdomen. A clean dressing is the prime rule of treatment. Castration is in order when the wound is lacerated and involves the major part of the gland. Inflammation of the testicle generally calls for castration.

Wounds of the spermatic cord generally consist of contusions, transverse, or oblique wounds. Hematomata are frequent. Injury to the vas is often followed by atrophy of the testicle. The treatment of wounds of the spermatic cord consists in the arrest of hemorrhage and a clean dressing.

Wounds of the scrotum by reduced-caliber bullets may be overlooked on account of the contractile character of the fibers of the dartos. The treatment of gunshot in this region consists of a clean dressing and strict antisepsis. The onset of infection should be treated by free incisions and thorough drainage.

Injury to Blood-vessels and their Lesions.—Lesions of blood-vessels from gunshot are more frequent now than formerly. The high-velocity projectiles cut vessels instead of pushing them to one side as formerly happened with lower-velocity lead bullets. These injuries may be considered under (1) contusion, (2) partial, and (3) complete division.

1. *Contusion* of an artery may be slight or severe. The former heals with no after-effects while the latter often ends in rupture from necrosis of the damaged area. If the rupture is complicated by sepsis, secondary hemorrhage occurs in ten to fifteen days from the time of injury. The resistance of the arterial coats may be so impaired as to end in traumatic aneurysm.

2. *Partial division* of an artery may result from a sharp spicule of bone, a fragment of shell, the short edge of a deformed bullet, or metallic fragments from a missile. A vessel may also be notched by high-velocity steel-clad bullets; and in arteries larger than the caliber of the bullet, the vessel may suffer perforation with two circular openings on opposite sides.

3. *Complete division* of an artery is followed by loss of pulsation in the distal distribution of the vessel if the collateral circulation is lacking, but where the anastomosis with other vessels is free, pulsation will be resumed later.

Wounds of veins differ in no way from those of arteries.

Traumatic Aneurysm.—This complication as a result of injury by gunshot has assumed greater importance with the use of steel-clad bullets. In the

Fig. 2885.—Traumatic Aneurysm of Radial Artery from gunshot wound by reduced caliber rifle bullet in the Russo-Japanese War. Treated by ligation and dissection of sac. Discharged cured. Base Hospital, Heroshima, Dr. Tanaka, I. J. Army, Chief Surgeon.

Civil War Otis records but seventy-four cases, while the statistics of the Franco-German war give one traumatic aneurysm for every 2,000 wounded. In the Anglo-Boer war where the reduced-caliber military rifle was extensively used, Graf found traumatic aneurysm in four per cent. of his cases suffering from some form of injury to blood-vessels.

There are two forms of traumatic aneurysm, namely, the diffuse and the circumscribed.

Diffuse traumatic aneurysm is the persistent effusion of blood in the tissues from a rent in a vessel. It is in reality a hematoma.

Treatment.—The treatment is similar to that for external hemorrhage from injury to a vessel's coats, namely, ligation of the vessel at the point of injury in the wound. The tumor should be laid open and the blood clots turned out in all cases demadding operative interference. If the bleeding vessel cannot be secured in the old wound, proximal ligature of it should be practised (Figs. 2885 and 2886).

Fig. 2886.—Traumatic Aneurysm of Right Brachial Artery from gunshot wound by reduced caliber bullet in Russo-Japanese War. Treated by ligation and dissection of sac. Discharged cured. Base Hospital, Heroshima, Dr. Tanaka, I. J. Army, Chief Surgeon.

Circumscribed traumatic aneurysms are smaller than the diffuse variety. They arise from a small opening in an artery which is surrounded by dense tissue like the popliteal space in which the hematoma has no room to expand. They have the expansile pulsation and bruit of spontaneous aneurysms, and they offer a more favorable prognosis than the diffuse variety.

Treatment.—Rest in bed will often cure these small tumors entirely. When the tumor shows a tendency to enlarge and rupture, ligation of the injured vessel above and below the point of injury and dissection of the sac should be practised. If this cannot be done the operation of Anel or that of Hunter may be resorted to.

Arteriovenous Aneurysms and Aneurysmal Varix.—These terms relate to arteriovenous communications. In arteriovenous aneurysms there is a communication between an artery and vein with an intervening sac between the two vessels. In aneurysmal varix the communication is direct, the two vessels being in contact. These arteriovenous communications were formerly the result of stab or punctured wounds, but the advent of reduced-caliber rifles has made it possible for projectiles to pass between vessels, thereby inflicting injury to the coats of each, which ends in the pathological conditions described. It has also been noted that the upper or under surface of two adjacent vessels may at times sustain injury from a passing projectile, which may later end in one of the forms of arteriovenous communications.

Symptoms.—In all such communications there are a pulsation, thrill, and bruit present, and they become more apparent after the disappearance of the primary swelling. The murmur is often referred to as a "machinery" murmur. The distinguishing feature between the aneurysmal varix and varicose aneurysm is the constant presence of a tumor with the latter. The prognosis of arteriovenous aneurysm is not so encouraging as that of aneurysmal varix.

Operative treatment is the most effective method for the relief of either form of arteriovenous communication. This unfortunately can be employed only in vessels of the limbs and more especially the upper limb in the case of the brachial and its accompanying vessels. Ligation of the artery above and below and as near as possible to the point of communication is the ideal operation. It is always preferable in any event to delay operation for some time. Varicose aneurysms under quiet in bed are often converted into the less serious condition of aneurysmal varix.

In arteriovenous communications involving the large vessels of the neck the most suitable operation is ligation of the main trunk on the proximal side of the sac. The sac consolidates and disappears in the course of a short time. Here also, it is preferable to avoid operation until it is rendered necessary. In some instances there is a tendency to spontaneous cure, but the tendency is toward increasing discomfort from the effects of the pressure of dilated vessels or from undue enlargement of the sac in the case of a varicose aneurysm.

Injuries of Peripheral Nerves.—Lesions to peripheral nerves are divided into those of (1) Concussion, (2) Contusion, (3) Partial, and (4) Complete Division.

(1) *Concussion* of individual nerves from gunshot by the high-power military rifle has served to increase the number of nerve lesions materially in war wounds. Such a lesion results from the vibratory effects which emanate from the projectile or, as often happens, from secondary projectiles which issue from the area of fracture of one of the long bones. The vibratory impulse which is thus received by a nerve will cause it to suffer temporary and at times complete loss of function with no visible evidence of injury to the nerve tissue. The amount of concussion so sustained is proportional as a rule to the amount of velocity and resistance in the bone at the moment of impact. Observers in recent wars have in addition noted certain degrees of concussion from the vibratory effects which the high-velocity bullet imparts to adjoining nerves when traversing soft tissues alone, independently of bone lesion.

Symptoms of Concussion.—Partial or complete loss of function including loss of sensation and motion are among the most common symptoms. In slight cases there are more or less complete anesthesia and tingling of a transient character in the skin supplied by the nerve involved. In more severe cases there is loss of motion and sensation such as occurs in complete division of a nerve, followed by trophic changes and wasting of muscles. In spite of apparent nerve degeneration, after a time these cases undergo a gradual improvement with entire return of sensation followed by restoration of motion.

2. *Contusion.*—This lesion differs from concussion to the extent that direct injury to the nerve has taken place from violence exerted by the projectile on some secondary missile. Contusion is generally more serious than concussion.

Symptoms.—The loss of motion and sensation is not complete. Trophic changes like redness of the skin, eczema, club-nails, pain, polished skin, loss of hair, etc., appear. Recovery is the rule. Sensation will be the first to return, and later motion will appear.

3. *Partial Division.*—This is one of the more common traumatism of nerve injury by gunshot. The symptoms and prognosis do not differ from those of contusion.

4. *Complete Division.*—This injury occurs most generally in smaller nerves. The large nerves are only bisected when a reduced caliber bullet is travelling at a tangent to its trajectory. Large nerves like the sciatic are only notched or perforated.

Symptoms.—Complete loss of sensation and motion at once take place. The muscles fail to react to the faradic current and the signs of degeneration and trophic changes set in later.

Treatment.—This is expectant, and operative, when necessary. Strict antisepsis should be employed at all times. Suppuration in a wound delays the union of nerves and prolongs restoration of function. After complete rest for about one month the galvanic current, gentle massage, and the movement of joints may be commenced.

Immediate Operation.—This is practised when in exploring a wound we find a nerve cut across.

Intermediate Operation.—In all cases we should wait a reasonable time for the signs of recovery that are sure to return in all minor cases like those of concussion, contusion, and partial division. Nothing is lost by a delay of about two months. When after this time restoration of function is not apparent, without return of sensation, the ends of the nerve should be sought and brought together with a small round needle, threaded with fine chromicised catgut or silk suture through the sheath of the nerve, using mattress stitch or Lembert suture. If the whole nerve cannot be brought together such parts and filaments that can be identified should be carefully sutured. When loss has been considerable, grafting the distal end to an adjoining nerve may be practised. In the after-treatment traction on the ends of the divided nerves is prevented by fixing the limb in a plaster-of-Paris splint for several weeks. Later prolonged treatment by means of electricity, massage, and gymnastics should be employed.

Operation for Secondary Involvement.—Operation is sometimes necessary when the function of a nerve is interfered with, by pressure in sac tissue or in callus. In such cases the nerve should be released and stretched. Traction on a nerve, from contracted scar tissue with no apparent lesion of the nerve itself will also require stretching in some cases to relieve pain and discomfort.

Wounds of Joints.—Marked beneficence has come from the use of reduced caliber bullets in all joint wounds. The pathological lesion by old time lead bullets favored the development of sepsis because of the extent of laceration and fissuring of bone into the joint and shaft of long bones. The lesion of steel-clad bullets is more limited. It consists of a small perforation with no fissuring except in proximal shots, and the reports from recent wars are most encouraging.

The changes that have been wrought in recent years from the use of antisepsis and the new armament are at once shown in the following tabular statement:[13]

Percentage Mortality from Wounds of the Joints in Five Wars

Joints.	American Civil War.	Franco-Prussian.	Japan-China (Haga).	Spanish-American.	Anglo-Boer War.
Hip	84.7	71.8	100.0	33.0	28.5
Knee	53.7	48.9	25.0	5.5	4.2
Ankle	26.9	24.0	0.0	0.0	0.0
Shoulder	31.1	35.5	0.0	0.0	3.7
Elbow	9.4	21.2	0.0	0.0	2.0
Wrist	12.9	12.6	0.0	0.0	0.0

Cases and Deaths in each Class of Joint Wounds in Three Recent Wars

Joints.	Japan-China War (Haga).		Spanish-American War and Philippine Insurrection.		Anglo-Boer War	
	Number.	Deaths.	Num. ber.	Deaths.	Number.	Deaths.
Hip.....	1	1	3	1	7	2
Knee.....	16	4	77	2	95	4
Ankle ...	4	0	26	2	40	0
Shoulder...	4	0	9	1	27	1
Elbow	16	0	44	1	49	1
Wrist	6	0	6	0	10	0
Total	47	5	165	6	228	8
Mortality, per cent.		10.6	...	3.6	.....	3.4

The Karbine statistics of 1905 during the Russo-Japanese War according to Follenfant give records of 1,382 joint injuries with only seven deaths and seventy-two resections. The latter were no doubt the result of artillery fire, because formal or even partial resections for lesions of the reduced-caliber rifles are seldom called for.

Vibration Synovitis.—A joint may be shocked by the dispersion of a bullet's energy as it passes through tissues near it, to such an extent as to cause what Mr. Makins has seen fit to call vibration synovitis. Whether minute fissures into the joint are present or not to answer for the appearance of certain symptoms it is difficult to state. Mr. Makins has seen effusion in joints when apparently soft parts alone had been traversed.

Fig. 2887.—Photograph in Case of Corpl. H. C. S., Co. "F," 122nd N. Y., shot March 27, 1865. Globular head of femur is shattered by conoidal ball which remains lodged. No. 9821. Army Medical Museum collection.

Wounds of joints are divided into the following: (1) Lesions of joints without injury to osseous structures. (2) Wounds of joints accompanied by lodged missile. (3) Lesions of joints marked by grooving of the articular ends of bones. (4) Perforation of articular ends across the joint. (5) Comminution of articular ends of bones.

1. *Lesions of joints without injury to bone* were seldom observed with the use of the old and larger-caliber bullets. Such wounds are more common with the reduced-caliber bullets, especially in the larger joints like the shoulder, hip and knee.

2. *Wounds with Lodged Missiles.*—Lodged missiles in joints were common in the days of low-velocity projectiles. They are still commonly seen with the use of modern shrapnell balls, pistols, and revolvers; and they are not infrequent with the use of the pointed bullet when it has lost its remaining velocity (Figs. 2887 and 2888).

Fig. 2888.—Private J. R. Co. "C" 69th N. Y. Wounded March 25, 1865. Died of exhaustion Apr. 6, 1865. Conoidal ball entered anteriorly and lies lodged in great trochanter. A fissure 6 inches long extends down the shaft from the point of lodgment. No. 98211, Army Medical Museum collection.

3. *Superficial Grooving of the Bone.*—In this class of wounds the joint is not always directly implicated, but the danger lies in the great liability to infection due to the character of the wound, such as the long superficial tear in the capsule of the knee especially. A perforation in and out of the capsule offers less danger. All wounds in the neighborhood of joints should be treated as joint wounds.

4. *Perforation of the Articular Ends Across the Joint.*—In perpendicular shots the joint surfaces are traversed by the shortest route and the amount of lesion and the dangers of infection are less.

5. *Comminution of the articular ends of bones* is frequently noted as a result of wounds by shell fragments, large lead bullets, shrapnell balls, and proximal shots near the muzzle of high-power military rifles. In this class infection is prone to occur as a result of the large external wounds and the comminuted bone which in turn inflicts extensive injury to soft parts.

Symptoms.—The earliest of the significant symptoms is effusion in the joint, composed of the products of inflammation and blood. The most positive sign of joint injury is escape of synovial fluid. When this is absent the diagnosis must rest from a study of the location of the external wounds. Joints may be implicated by fissures from an adjoining fracture, and when a joint becomes septic from an adjoining injury, implication by fissuring is very probable.

Treatment.—The treatment of joint injuries by gunshot is divided into (1) amputation, (2) excision, and (3) conservative treatment.

1. Amputations are seldom called for now in joint wounds by gunshot. Primary amputation is only resorted to for great destruction of the joint and interference to the blood and nerve supply such as occurs

from shell wounds. No amputation was required in either the Spanish-American or Anglo-Boer wars for injury from jacketed rifle bullets.

2. Primary excisions are also seldom called for. Partial excisions such as the removal of loose fragments of bone are at times required from injury by shell fragments or shrapnell balls, but formal excisions have wellnigh disappeared from the field of military surgery.

3. Conservative Treatment.—This is by far the most commonly employed mode of treatment in joint wounds. It is used in all joint injuries, moderate or severe, except in those cases which have sustained irreparable destruction of the joint structures, the nerve and blood supply, and which demand amputation.

In simple joint wounds exhibiting perforation with little or no splintering of the epiphyseal ends of bones a clean dressing to a clean field and immobilization are the only indications of treatment. Passive motion and gentle massage should be employed as soon as the external wounds have healed.

In the more severe injuries exhibiting laceration of tissue, splintering and loose fragments of bone, the wound should be irrigated with a solution of bichloride 1–4,000, loose fragments removed, and the wound dressed, drained if necessary, and then immobilized.

In the emergent conditions of active campaign the surgeon is never sure of being able to carry out all the details of the conservative method. Immobilization by extension and counterextension is sometimes difficult or impossible. When transport is necessary, under trying conditions, the chances of saving life may be better by resorting to amputation. In this way military surgeons are often compelled to sacrifice limbs—lower limbs especially—that could be easily saved in fixed hospitals. An amputated limb will stand transport better than a comminuted joint, hence the advisability of a primary amputation under certain field conditions.

If suppuration sets in when the surgeon is attempting a conservative plan of treatment, free incisions, irrigation, and drainage should be employed at once.

Wounds of the Shoulder.—A wound of this joint is often complicated by wounds of adjoining parts like the forearm and hand, the face, neck, thorax, clavicle, or scapula.

Gunshot wounds of the shoulder are not as frequent as formerly. In the Civil War they occurred in sixteen per cent. of all joint wounds, and in two per cent. of all wounds in the Franco-German War. Out of 4,919 gunshot wounds in the Spanish-American War and Philippine Insurrection there were but nine gunshots of the shoulder-joint reported, with one death. Four of the men were restored to duty, one was discharged at expiration of term of service, and three were discharged and pensioned.

Treatment.—The large majority of wounds of the shoulder are amenable to treatment by expectancy or conservation. If fragmentation is present, loose spicules should be removed through the exit wound which should be enlarged when necessary. Irrigation with a solution of boric acid or bichloride of mercury 1–4,000 should next be made, drainage provided for; and, after applying a clean dressing the limb should be immobilized.

Primary excision is seldom resorted to on account of the effective methods of modern treatment, and the favorable lesion incurred by the present-day rifle bullets. In preantiseptic times excisions were resorted to. A formal excision was less frequently followed by the development and after-effects of sepsis. The cases were more safely handled in transport and in the crowded conditions of the hospitals.

Amputation as already stated is only indicated for very severe comminution with destruction of the nerve and blood supply. Secondary amputation or excision is at times necessary in those cases in which conservation has failed. Necrosis of a large portion of the humerus, osteomyelitis, gangrene, and secondary hemorrhage were the complications which led to amputation in preantiseptic times.

Wounds of the Elbow.—The frequency of gunshots of the elbow ranks next to that of the knee. They lend themselves especially to the conservative mode of treatment; it is the method of choice in the modern treatment of all elbow-joint wounds short of those

Fig. 2889.—Skiagram Showing the Result of Gun-shot by the .30 cal. Krag-Jorgensen bullet in a U. S. soldier who was shot at a distance of 5 feet, in Oct., 1901. He was treated in accordance with modern methods by removing all detached fragments, etc. There is excellent use of the arm. Exposure was made in 1911. Lettermann General Hospital Laboratory.

lesions which demand excision or amputation. In those injuries in which the blood supply is badly compromised, the surgeon in fixed hospitals is often rewarded by success after the painstaking details of a conservative mode of treatment. It is generally otherwise in military practice. Experience has taught us that the surgeon errs on the safe side if he amputates when there is injury to the brachial artery regardless of the chances of the reëstablishment of the collateral circulation through the rich supply of vessels about the elbow-joint. No primary excision of the elbow was done in either the Spanish-American or Anglo-Boer War.

The after-treatment under any plan of treatment should guard against malposition of the forearm and hand. The forearm should be flexed on the arm at a trifle less than a right angle and the hand should occupy a position half-way between pronation and supination, the thumb pointing upward. The fixation apparatus should be provided with windows to permit redressing of the wound without disturbing the attempt at immobilization.

Wounds of the Wrist and Carpus.—Lesions of this joint depend upon the size and velocity of the projectile inflicting the injury. The effects of modern military bullets are less likely to show comminution of the articular ends of the radius and ulna or carpal bones. No deaths are reported from gunshots of the wrist in either the Spanish-American or Anglo-Boer War.

Conservative Treatment.—The functions of the hand and fingers are best promoted by avoiding the development of sepsis in the wound. The rules of conservative treatment include rigid antisepsis, removal of loose fragments when necessary, and immobilization.

Complete or partial excision gave very discouraging results in preantiseptic times, as a result no doubt of inflammatory deposits in the tissues of the hand and wrist. Under our modern methods of treatment we expect to have useful hands and fingers after excisions of the wrist.

Primary amputation is required only after extensive lesion of the soft parts and bony articulation from shell fragments, the larger rifle projectiles and wounds exhibiting explosive effects from the modern rifle and shotguns at very close range.

Wounds of the Hip-joint.—Fischer's statistics give thirty gunshots of the hip for every 1,000 wounded in all anatomical parts, and five per cent. for all joint wounds. Of the large joint injuries those of the hip were the most fatal. In Otis' table there are 386 cases reported from both the federal and confederate armies. If we divide the cases into two groups: one where the acetabulum is involved in the lesion and the other where it is not, we find the former gave a mortality of 96 per cent. after a conservative mode of treatment, and in the latter, in which the acetabulum was not involved, the mortality was 58 per cent. The two groups gave a very high mortality regardless of the anatomical parts involved when amputation or excision was performed. In acetabular involvement there were no doubt complications of a serious nature about the pelvis to develop during the clinical history of the cases. Under our modern methods of treatment, lesions of the hip-joint, uncomplicated by internal injuries, the results of hip-joint wounds will be attended with a much lower mortality.

Diagnosis.—The *x*-ray has made the diagnosis of hip-joint injury very easy in the majority of cases. Since the physical signs of fracture such as shortening of the limb, eversion of the foot, disturbed relations of the bony points about the joint, and escape of synovia are often absent, injury to the hip is often obscure without *x*-ray evidence. This difficulty in diagnosis is very much emphasized by the use of reduced-caliber bullets. Perforation or grooving of the head, neck, and trochanters of the femur are now very common. A complete solution of contiunity seldom occurs so that the physical signs of fracture are frequently absent. In such cases one has to take account of the location of the external wounds. In cases of doubt the surgeon should treat all injuries close to the joint as hip-joint wounds.

"In the absence of the *x*-ray as an aid to diagnosis, or in cases in which the plate may show an obscure finding, there are signs which the surgeon should look for. Langenbeck laid stress on swelling of the capsule with blood which is most apparent on the front of the thigh just below Poupart's ligament. The pressure of the tumor back of the large vessels causes the femoral artery to pulsate perceptibly under the skin of the groin. Again in through-and-through shots the exact location of the "dangerous region" in hip cases as laid down by Langenbeck must be carefully mapped out. According to him the "dangerous region" is included in "a triangle whose base intersects the trochanter major, while the femur and the anterior superior spine of the ilium form the points of an acute angle." Stevenson suggests a dangerous space included in "a triangle the angles of which are at the spine of the pubes, the anterior inferior spine of the ilium, and the outermost point of the great trochanter. The value of any space, defined by invariable lines, is necessarily faulty. This was true in the days of the old armament, and it becomes more so with the use of present-day rifle bullets. The joint capsule may be penetrated by reduced-caliber bullets anteroposteriorly or *vice versa* time and again without implicating the osseous structures, by passing above or below the neck of the femur."

Treatment of Gunshot Wounds of the Hip.—The management of gunshot of the hip has hitherto been considered under the following heads: (1) Expectancy, (2) Conservation, (3) Excision, (4) Amputation.

Expectancy contemplates a strictly *laisser faire* policy with the exception of a clean dressing and immobilization. No exploration is permissible. The plan is applicable in many cases of gunshot about the hip from the present armament involving doubt in diagnosis, or in those cases of slight injury by steel bullets which nearly always heal without complications. The plan has been practised with remarkable results in the Spanish-American, and all of the recent wars.

Conservative Treatment.—When a positive diagnosis of joint injury has been ascertained, under this plan of treatment if interference is deemed necessary, the surgeon may employ exploration of the joint; removal of loose fragments and lodged missiles; and immobilization after the application of a clean dressing. Lesions calling for conservation usually arise from injury by smaller shell fragments, large lead bullets from rifles or pistols and shrapnell balls. Out of eight cases treated conservatively in the Spanish-American and Boer Wars, from different kinds of missiles, the mortality was 27.2 per cent.

Exploration may easily be done through the exit wound which should be enlarged when necessary. After the removal of loose fragments and foreign bodies the joint and wound are properly irrigated and the limb immobilized.

Immobilization is often a most difficult problem in war surgery. In the face of enforced transport it is next to impossible. We have succeeded in transporting such wounded successfully under very trying conditions when the number of cases was limited. In war, when the casualties overwhelm the working capacity of a limited personnel, it is better to treat such wounded near the seat of battle, and defer transportation to general hospitals to a later period.

We have found plaster-of-Paris splints preferable for all joint and shaft injuries in war. When the material is not at hand the surgeon is to depend on wire gauze splinting, extension, and counterextension if practicable.

The onset of suppuration should be met by free drainage and frequent irrigation with antiseptic solutions like bichloride of mercury 1–4,000. Such cases are often long continued. They should be stimulated and well nourished in order to prepare the patient for the measures of surgical relief that may become necessary later.

Excision of the Hip.—Primary excision of the hip has been almost entirely supplanted by the conservative plan of treatment, since the employment of modern methods of treatment and the use of steel-clad bullets. The mortality in the primary stage was 96.9 per cent. in preantiseptic times (Otis); and we have reason to believe it would still be great under modern conditions, from shock and hemorrhage.

Intermediate excisions are no longer undertaken. The mortality in preantiseptic times was most discouraging. We now aim to delay the necessity for excision by the employment of drainage and the free use of irrigation to a time when secondary excision becomes a safe procedure.

Secondary Excision.—This method of treatment is undertaken when all efforts at conservation have failed. Secondary excision is done to remove necrosis of bone from unextracted loose fragments, and fragments originally attached which have subsequently become loose. Secondary excision for these reasons does not differ from secondary excisions met with in civil hospitals from other causes, and the operation generally employed is the same for both classes.

Amputation of the Hip.—Primary amputations for gunshot in recent wars are not reported in the literature. We must await the government reports from the Manchurian and Turko-Balkan campaigns for data which may bear on the value of such an operation under modern conditions.

In the Civil War the fatalities after the operation were very great. In an aggregate of 250 cases collected by Otis, sixty-six of which occurred in our Civil War, the mortality after primary amputation was 89.1 per cent.

In three secondary disarticulations in the Spanish-American War there was one death; and in thirteen cases in the Anglo-Boer War there were eight deaths, making an aggregate mortality of 56.2 per cent. for the sixteen cases in these two wars.

the tibia and condyles are widely separated and there is ample space for a bullet to traverse the joint in its anterior third transversely behind the patella without touching bone. Examples of wounds of this kind are more frequent now than formerly, and they have been fairly common in recent wars.

Lodged balls in the joint unattached to bone have been noted. They are generally imbedded however in the surface structures. Under our present methods of diagnosis with the *x*-ray such cases are easily detected and successfully treated (Fig. 2890).

Guttering of bony surfaces of the joint is one of the frequent lesions by the new armament. Complete perforations traversing the joint have become more common with the use of the new armament. They are the rule in the mid ranges when traversing the

Fig. 2890.—Radiogram Showing Postero-anterior and lateral Views of Knee in Case of Private William R. B., 29th Co., U. S. Coast Artillery. Exposure was made in 1909. This man was shot prior to enlistment with a .38 cal. Smith and Wesson revolver and the presence of the missile in the knee was not detected until he had been in the service some time. The washers were used as localizers. Army Medical School collection.

Wounds of the Knee-joint.—On account of its exposed position and greater volume, wounds of the knee were more numerous in former times than those of other joints.

We divide wounds of the knee into those in which there is a (1) simple perforation of the synovial sac; (2) injury to some of the joint structure with lodged ball; (3) injury showing guttering of articular ends of bones; (4) injury with complete perforation of articular ends in different directions; and (5) implication of the joint from fissures and comminution of the bones entering into its formation.

Simple perforation of the capsule occurs from injuries by sufficiently small projectiles traversing the joint anteroposteriorly in a line just below the patella, when the limb is in any position except that of extreme extension. There is also sufficient space from side to side under the extensor muscles for a ball of moderate diameter to penetrate the synovial membrane; again, when the knee is slightly flexed, patella, condyles of the femur, and upper surface of the tibia. Perpendicular shots crossing the joint by the shortest route inflict less injury and they are attended with good results as a rule.

Implication of the joint by fissures from adjoining fractures arises generally from lesions by shell fragments and shrapnel balls. The diaphyses of the femur and tibia immediately adjoining the joint surfaces are made of compact bone so that comminution of the shaft above or below the joint in the immediate vicinity of the epiphyses will fissure the latter into the joint. Such an occurrence is rare with the use of steel-clad bullets except at proximal ranges.

Diagnosis.—The diagnosis of wounds of the knee is generally easy. Swelling from effusion of blood, inability to move the knee, and pain on motion are valuable signs. A study of the location of the apertures on the skin will also form a guide. Fracture may be attended by displacement which is an absolute sign. The *x*-ray evidence will point to the

amount and kind of lesion and the presence of lodged balls.

Treatment.—The results of gunshot wounds of the knee are now cited by all authors because of the striking evidence which has come from the employment of the new armament and the use of antisepsis in recent times.

The rules of treatment in preantiseptic times were (1) amputation, (2) conservation, (3) excision. Among these plans of treatment, amputation was the method of choice, and excision was only resorted to when the patient refused amputation. In 2,431 amputations for gunshot fracture the mortality was 56.6 per cent. when amputation was done through the knee, and 53.6 per cent. when it was done through the lower third of the thigh (Otis). The experience of von Bergmann in the Russo-Japanese War of 1877–78 emphasizes the value of antisepsis in gunshot injuries by the old time armament. In fifteen cases of gunshot fracture of the knee treated by carbolic dressings he had fourteen recoveries. Only two of the cases suffered amputation. The experience of Reyher in the same campaign in eighteen primary aseptic cases, dressed antiseptically was quite as successful. His mortality was 16.6 per cent. The treatment was entirely conservative. The employed weak carbolic irrigations in severe cases, while simple cases were cleansed and dressed with wet carbolic acid gauze. Those who recovered, had useful joints. Grouped together the cases of von Bergmann and Reyher give an aggregate mortality of only 11.1 per cent. in favor of antisepsis.

In the Spanish-American War and Philippine Insurrection we have records of seventy-seven cases all told with a mortality of 6.5 per cent. The British report ninety-five cases in the Anglo-Boer War with a mortality of 4.2 per cent. The British performed amputation in 11.5 per cent. of their cases which were the result of shell fragments. The results in the Spanish-American and Anglo-Boer Wars exhibit in a striking way the beneficence which arises from the use of the new armament and the modern methods of wound treatment. When the injuries of the knee arise salely from the use of reduced caliber bullets the results are still more striking. Out of seventeen such cases at Santiago by the Spanish Mauser there was no death; fourteen of the men were restored to duty and but three were discharged on surgeon's certificate of disability.

Conservation should be the rule of treatment in nearly all gunshots of the knee by military rifle bullets. In the simple cases no attempt should be made to explore the wound except to remove pieces of clothing or foreign bodies when these are present. In cases of gunshot of the patella alone, the treatment pursued is similar to that for injury to the knee.

Splintering and fragmentation of the tibia and femur as demonstrated by palpation call for exploration and the removal of loose fragments. When additional room for diagnosis becomes necessary an incision may be made on one or both sides of the patella, or a horseshoe flap, convexity downward, should be raised as recommended in excision of the knee. After dividing the ligamentum patella, and the lateral and crucial ligaments, ample room will be found for diagnosis and operative interference. Following the removal of loose fragments, lodged missiles, etc., the wound and joint surfaces should be irrigated with a weak antiseptic solution. The incised surfaces are next brought together with sutures and drainage should be provided for. The latter should remain in place not longer than forty-eight hours. The limb should be dressed and next immobilized upon a fenestrated wire or plaster-of-Paris splint.

The presence of suppuration in such a wound calls for prompt incision and drainage. Ankylosis is the rule in cases that recover after the onset of sepsis or cases that recover after extensive comminution.

Excision at any time has never been a favorite operation in knee cases.

Primary amputation for injury to the knee is only employed in shell injuries which exhibit extreme traumatism of bones, soft parts, and large vessels.

Wounds of the Ankle.—In this important articulation where the important parts of the joint occupy such a limited and compact space, the lesion is very much influenced by the sectional area of the projectile. Shrapnel balls and shell fragments generally inflict injuries of a severe nature and those of the latter especially more often call for amputation.

The *astragalus* is generally grooved or perforated by small steel bullets. In the mid ranges, perforation of the bone is the rule if the impact is against the body of the bone. At close and nearby ranges there is fissuring or there may be comminution amounting to pulverization of the bone, the wounds of entrance and exit being filled with bony sand. The *external malleolus* will show the grooving and perforation ordinarily seen in epiphyseal tissue but the *fibula* higher up is very brittle and it ordinarily exhibits comminution instead of perforation. The part of the *tibia* entering into the formation of epiphyseal tissue is composed of the internal malleolus and about one-third inch of the lower end of the bone. This tissue when injured will show the usual characters of perforation or grooving.

The treatment of gunshots of this joint will be taken up under (1) conservation, (2) excision, and (3) amputation.

Conservation.—This mode of treatment has only gained favor since the introduction of our modern methods of wound treatment and the advent of the modern military rifle. The opportunities for the development of infection in wounds of the lower limb which are great at all times, caused the older surgeons to class gunshots of the ankle among the fatal war wounds, and the rule of treatment in the days of Sarrey, Thompson, and Guthrie was amputation in all cases in which musket balls had lodged or passed through the ankle. Conservation was not popular with the surgeons of our Civil War. In the less severe cases so treated the mortality was 19.5 per cent. In 1,711 gunshot fractures of the bones of the ankle joint only 518 were treated by this method.

In the Spanish-American and Boer Wars the surgeons, employed conservation in nearly all cases. Our reports for the years 1898 to 1901 give record of twenty-six cases with two deaths. Eleven of the men were restored to the colors and thirteen were discharged for disability. In the Anglo-Boer War Hickson[12] reports forty cases with no deaths, although infection was present in twenty-eight of the cases.

The wound should be dressed antiseptically and fixation applied at once. At the first opportunity exploration should be undertaken whenever the presence of comminution renders surgical interference necessary. Loose fragments can generally be removed through the exit wound, which is easily enlarged when necessary. Severed tendons are brought together by catgut or silk-worm gut suture. When a drain is necessary it should not be kept in place more than thirty-six hours. The presence of inflammation is generally met by free incision, drainage, and frequent irrigation with antiseptic solutions. The after-treatments consist of massage, movement of the toes, friction, and faradization.

Excision of the ankle is not practised after gunshots. It was at no time a favorite operation in military surgery on account of the painful joint which was an invariable sequela of such an operation. The restoration of function is very unsatisfactory, and all cases that call for such a radical operation as excision fare better after a primary amputation.

Amputation is performed in all cases of extreme traumatism that are in no way adopted to conservation. There were eleven amputations in the forty

ankle injuries reported by Hickson in the Anglo-Boer War. Artillery wounds were responsible for five of the amputations.

Wounds of the Diaphyses of the Long Bones.—Fractures of the long bones are of special interest to the military surgeon since they form a large percentage of war injuries. They are varied in character and often serious and finally they offer great difficulty in transport.

Fractures of the Humerus.—The results of fractures of the long bones since the advent of steel-clad bullets and the modern methods of treatment have been most encouraging and they have been especially so in gunshots of the humerus. Of eighty-seven gunshot fractures of the humerus reported by the surgeon-general of our army for the years 1898–1901 inclusive which occurred during the Spanish-American War and Philippine Insurrection there were but five deaths. Thirty-nine were restored to duty, twenty-nine were discharged for disability, and twelve were otherwise disposed of. Ten amputations and one resection were performed; fragments were removed in a few cases and incision for drainage was done in one case.

Hickson gives eighty-three cases of fracture of the humerus in the South African War. Fragments were removed in twenty-two cases. The amputation rate was 15.6 per cent. More than one-third of the eighty-three cases were septic. The mortality for all cases was 3.6 per cent.

Conservative Treatment.—Conservation is to be practised in all gunshots of the humerus except in cases of extreme traumatism that call for amputation. Excision in continuity is not to be recommended. Consolidation of fragments in all comminuted fractures will take place provided they are still attached to periosteum or soft parts. Attached fragments should be replaced in their original position as much as possible. The wound should next be cleansed, irrigated, drained and immobilized with a plaster-of-Paris dressing. Nerve lesions from pressure by callies is one of the frequent after-effects of fracture of the humerus by gunshot. Non-union which is noted in fractures of this bone from other causes is happily rare in fractures from gunshot.

Fractures of the Forearm.—Fractures of the forearm constitute fifteen per cent. of all fractures in war. Anteroposterior or posteroanterior shots are attended with fracture of but one bone while oblique or transverse shots include lesions of both bones. The amount of fragmentation of either bone is generally extensive because of the brittle nature of the osseous structure about the shaft of these bones. The explosive type of fractures is common in the lower third of the forearm, and the proximity of the vessels to bone makes hemorrhage common in these wounds.

Of 114 gunshot fractures of the forearm in the Spanish-American War amputation was called for in 8.3 per cent. of the cases. Forty-nine per cent. of the 114 cases were restored to duty, the remainder were mustered out and discharged for disability. Only one death is recorded.

Out of sixty cases in the Anglo-Boer War there was no death. Amputation was performed in three cases.

In our Civil War out of 5,194 gunshot fractures of the forearm there were 1,007 primary amputations with a mortality of 9.5 per cent. There were 1,000 excisions. This mania for operative work is ascribed by Otis to the number of "inexperienced medical officers, hastily summoned to the field in emergencies." The tendency to do mutilating operations diminished with experience and the duration of the war.

Wounds of the Hand.—The most rigid antisepsis should be practised for all wounds of this locality because of the tendency to sepsis. The whole hand should at once be painted with one of the iodine preparations or thoroughly scrubbed with soap and water and the wound irrigated with a solution of mercury bichloride 1–4,000. Loose pieces of bone should be removed, drainage provided for and often the application of a proper dressing; the hand and arm up to the elbow should be immobilized. Free incisions should be made if suppuration is impending, and a continuous antiseptic bath should be employed.

Fractures of the Femur.—There were 302 gunshot fractures of the femur in the Spanish-American and Anglo-Boer Wars from the effects of modern armament and treated under modern methods with a mortality of 15.8 per cent. If we compare these results with those in the Civil War we find a great reduction in mortality in favor of those occurring under modern conditions. The mortality in the Civil War of 6,576 gunshot fractures of the femur was as follows:

Upper third	49.7 per cent.
Middle third	46.1 per cent.
Lower third	42.8 per cent.

The general mortality was 46.2 per cent. If we compare this with the general mortality in the two recent wars mentioned we find a gratifying reduction of 30.4 per cent. in favor of modern methods of treatment and the use of the modern armament.

Treatment by Conservation.—This method of treatment is used in all cases except those attended by extreme comminution, destruction of soft parts; or of the blood and nerve supply. Conservation in injuries of this bone is done in the same way that has been recommended in other long bones. Exploration is done under strict antisepsis by enlarging the wound of exit. All loose fragments detected by digital examination are removed, the wound is next irrigated with an antiseptic solution, proper drainage is instituted and maintained for thirty-six to forty-eight hours; the limb is dressed and then immobilized from the foot to the pelvis. Under any condition in war plaster-of-Paris is preferable for immobilization, and this is especially true when transport becomes necessary. In the absence of plaster-of-Paris Hodgen's splint is to be preferred.

Excision was never a favorite mode of treatment and it should not be undertaken as a formal operation. Loose fragments may be removed at the risk of leaving a gap of one or two inches in the long bones with the chances that nature will in time supply the deficiency and it is better to do this than formally to exsect.

Amputation.—This mode of treatment is applicable in all cases which cannot be treated by the conservative method with safety. Amputation is necessary when a limb has been entirely or partly torn away by a large projectile or shell fragment; in extensive comminution by shell fragments; or in comminuted fractures with destruction of the great vessels and sciatic nerve. In cases where there is doubt, the emergent conditions in war often weigh on the side of amputation. Enforced transport and the lack of trained assistants often compel amputation in military surgery for cases that could ordinarily be treated very successfully in civil hospitals.

Out of 303 gunshots of the femur in the Spanish-American and Anglo-Boer Wars[1] there were 59 amputations with a mortality of 42.5 per cent. This mortality is higher than one expects for cases treated under modern conditions. In the Crimean War the mortality in 1,666 amputations was 91 per cent.; in our Civil War out of 6,229 amputations there was a mortality of 53.8 per cent. Nearly all the fatalities in preantiseptic times resulted from sepsis and we regret to find that the large majority of deaths in the Spanish-American and Anglo-Boer Wars was due to the same cause. We have to admit that military surgeons are working under great difficulties in war and that the confusion incident to field work is not conducive to the

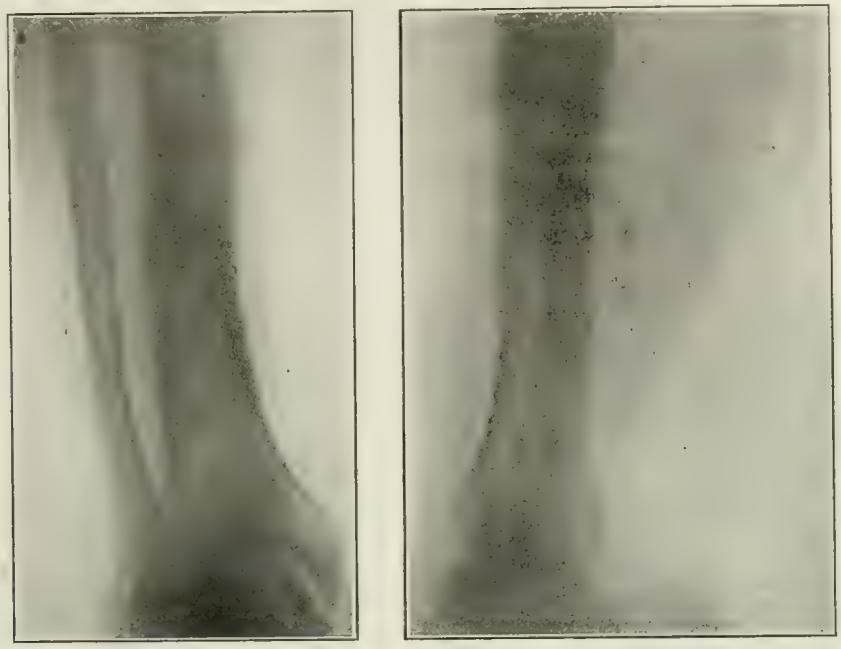


FIG. 2891.—Radiograms Showing Postero-anterior and Side Views in the case of Captain James H. McC.

technique of the clean operating room. We nevertheless believe that a strict application of the rule in conservative methods can materially reduce the above-noted mortality. Exploration should be pursued in all cases of doubt; loose fragments should be thoroughly cleansed away from the area of fracture; irrigation and good drainage having been established the limb should next be immobilized, and transport should certainly be delayed in every case where the resources of modern treatment can be employed.

Fractures of the Leg.—The tibia and fibula are harder than the long bones generally. From the exposed position of the bones in the lower part of the leg, the fractures show more comminution than we find in other long bones. The statistics of war hospitals in preantiseptic times show that one-third of the fractures of the long bones were found in the leg and that they aggregated as much as three per cent. of all war wounds.

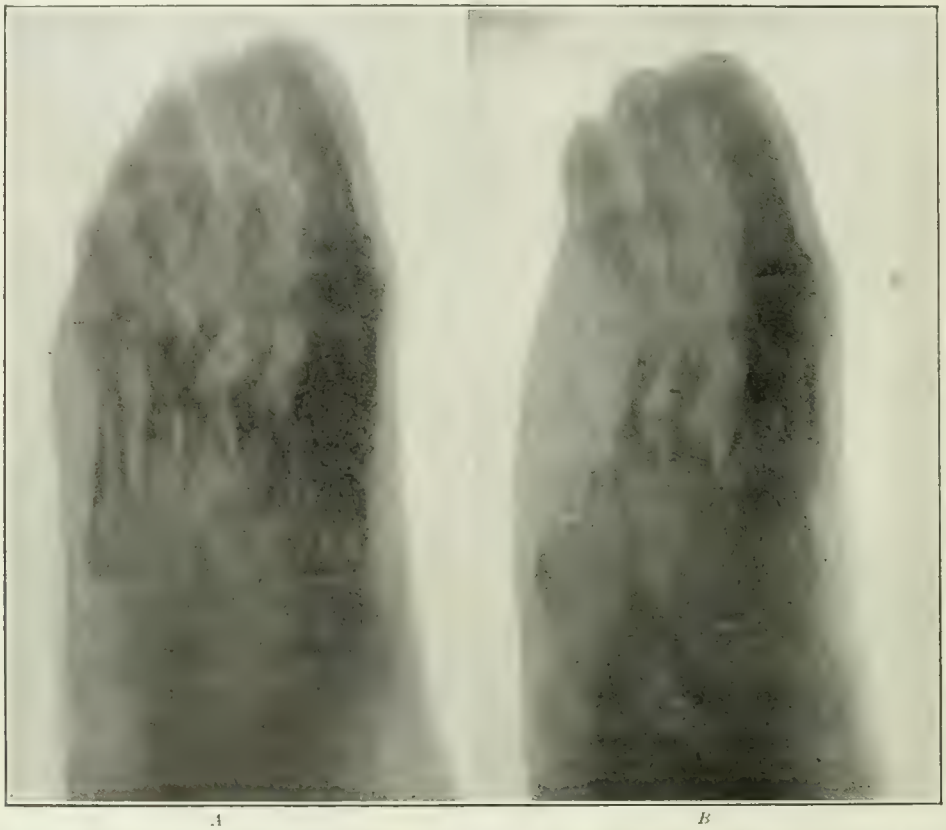
Treatment by conservation has supplanted all methods in modern times with the exception of primary amputation which is occasionally done for extreme destruction of soft parts with injury to the tibial arteries. We treated 146 gunshot fractures of the leg in the Spanish-American War with a mortality of 4.1 per cent. In 15 amputations the mortality was 13.3 per cent.

The British treated 137 cases. Their cases treated under strict conservative treatment showed the same good results as those mentioned for our army. They report thirty-two amputations with a mortality of 25.2 per cent. The mortality of the forty-seven amputations for these two codes is 21.2 per cent. In nearly all of these cases amputation was on account of sepsis. If we take the same class of cases in the Civil War we find in Otis's statistics a mortality of 32.2 per cent. out of 1,490 amputations in the intermediate and secondary stages. In other words we have saved but 11.2 per cent. of our amputated cases by our modern methods over the surgeons in our Civil War who treated their wounded in the preantiseptic era. A field mortality of twenty-one per cent. under modern conditions seems too high for amputation of the leg after gunshot. We have reason to believe that strict compliance with conservative

FIG. 2892.—Photograph in Case of W. A., Co. "L," 8th U. S. Inf. Gunshot fracture received in action in Philippines, Dec., 1906. Nature of weapon unknown. Amputation Oct., 1908. Photograph represents femur after amputation, it shows the later bone lesions that result from failure to remove loose fragments promptly from a comminuted fracture, a common condition in Civil War days. Army Med. School collection. From X-ray Laboratory, Lettermann Genl. Hospital.

methods would in the first place reduce the necessity for amputation in a large number of instances. Proper conservation should reduce the necessity for amputation to those instances where a limb is finally amputated for absolute loss of function, malposition of a foot, pain, etc. In such cases final amputation should be attended with no mortality whatsoever. We believe that the principal error which is committed in the conservative mode of treatment is in not removing loose fragments sufficiently and thoroughly when the wounds are first explored. If this were done properly and free drainage instituted, the results of the conservative method would be better, and the necessity for amputation in the active inflammatory stage would seldom occur. We are aware of the great difficulties which the relief corps labor under in field work. We are only calling attention to the subject of a high mortality after amputation in order to remind field surgeons of the extreme necessity for radical methods in conservation.

"The following case exhibits the excellent results attainable under modern conditions: Captain James H. McC., 1st U. S. Vol. Cavalry (Rough Riders), was shot at the battle of Guacimas during the advance on Santiago, June 25, by a Spanish Mauser bullet. The bullet entered posteriorly and to the tibial side of the left leg five and one-half inches above the internal malleolus. It smashed the tibia at this point badly and fractured the fibula. There were three small wounds of exit on the anterior surface of the leg just below the level of the wound of entrance. The wound was at once dressed with a field dressing. At noon the next day the writer assisted in operating upon the patient on the hospital ship *Olivette*. While the patient was under ether we found the area of fracture in the tibia marked by the presence of a number of small pieces of loose bone near the wounds of exit. The Mauser bullet had separated from its jacket and a number of pieces of the core and envelope were also removed. The wound was thoroughly irrigated with a 1–2,000 bichloride of mercury solution and then immobilized. In March, 1913—nearly fifteen years after the occurrence—the writer was able to secure a skiagram of Captain McC.'s leg. There is no deformity in the fibula, and but little deformity in the tibia. Particles of lead from the core of the bullet are still embedded in the tissues. There is three-fourth inch shortening and some limitation of motion in the ankle as a result of injury to the tendo Achillis (Fig. 2891).



A *B*

Fig. 2893.—*A* shows the result of a transverse shot through metatarsal bones of foot in a soldier at Santiago by a Mauser bullet. Radiogram was taken 22 months after injury. Callus formations were painful in sole of foot on walking. *B* shows foot after we had amputated two toes and part of corresponding metatarsal bones of *A*. Radiogram taken 25 months after injury. Army Medical School collection. U. S. Soldiers Home X-ray Laboratory. Dr. A. B. Herric, X-rayist.

Without the prompt and radical treatment that was practised in this case, there would have been long-continued inflammation of the surrounding tissues, and all the bone lesions that are common to such injuries.

Fig. 2892 illustrates the ulterior effects of the old-time practice in bone lesions of gunshot wounds when expectancy and conservation were restricted largely to the efforts of nature.

Wounds of the Foot.—The great difficulty which attends treatment of gunshots of this region in war is the presence of sepsis in the majority of cases. The opportunity to dress wounds in battle is often delayed so that the dirt from shoes, boots, and stockings which

soils the skin and which has entered the wound with the bullet, sets up sepsis before the majority of the cases have received the attention of the surgeons.

The mortality in gunshot fractures of the foot in our Civil War, largely as a result of sepsis, was 8.3 per cent., and 7.8 per cent. in the Franco-German War of 1870–71.

In 158 cases of gun shots of the metatarsus and toes in the Spanish-American War our mortality was 1.8 per cent.

Treatment.—Amputation is indicated in nearly all cases of wounds by shell fragments. Conservation is to be employed in the large majority of cases. Secondary excisions may become necessary when conservation fails or for painful callus. Transverse shots across the foot by steel-jacketed bullets cause much comminution and unless the loose fragments are entirely removed on exploration, suppuration will lead to excision and amputation later (Fig. 2893).

LOUIS A. LAGARDE.

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Gurjun Balsam.—Wood Oil. A viscid, copaiba-like turpentine, obtained from half a dozen or more majestic Asiatic trees of the genus *Dipterocarpus*. The "balsam" is collected by making deep "boxes" or gashes in the trunk of the tree, scorching them, and fitting a bamboo spout to their lowest parts. The yield is very great, and the drug forms quite an important article of commerce in the East. It is officially recognized by the Indian Pharmacopœia, and extensively used there as a substitute for copaiba. In other countries it is considerably used to adulterate the latter drug.

It is an intensely fluorescent, thick liquid, of a mild, terebinthinous odor, and a bitterish, aromatic taste. By transmitted light it is of a deep sherry color, and perfectly transparent; by reflected light it appears opalescent and greenish-gray. It is soluble in chloroform and the essential oils, but not completely so in alcohol. It consists of thirty or forty per cent. of a mild-smelling essential oil associated with a composite resin, composed of a crystalline *gurjunic acid*, and an amorphous portion. As it is collected from several different trees, its appearance, and also probably its composition, are subject to considerable variation.

USES.—In India and Asia generally as a substitute for copaiba in the treatment of gonorrhea, etc., and as a varnish. It is seldom or never used in this country.

W. P. BOLLES.

Gurlt, Ernst Julius.—Born in Berlin, Prussia, September 13, 1852. In 1848 he received his doctor's degree from the University of Berlin, his thesis bearing the title. "De ossium mutationibus rhachitide effectis." From 1852 to 1856 he was an assistant in B. von Langenbeck's Clinic, and in 1862 he was made an extraordinary professor in the university. He held various surgical positions during the military campaigns of 1848, 1864, 1866 and 1870 to 1871. He died January 18, 1899.

For a long period of years Gurlt was the managing editor or secretary for the Deutsche Gesellschaft für Chirurgie; and finally the Society elected him an honorary member. According to Pagel, he was one of the most learned surgeons and at the same time one of the most facile writers of modern times. The list of his published writings is very long; only a few of them may here be mentioned: "Beiträge zur vergleichenden pathologischen Anatomie der Gelenkkrankheiten," Berlin, 1853; "Ueber die Cystengeschwülste des Halses," Berlin, 1855; "Ueber den Transport Schwerverwundeter und Kranker im Kriege," Berlin, 1859; "Handbuch der Lehre von den Knochenbrücken," 1860 to 1865; "Leitfaden für Operationsübungen am Cadaver, etc.," Berlin, 1862 (6th edition, 1885); "Die Kreigschirurgie der letzten 150 Jahre in Preussen," Berlin, 1875; and "Geschichte der Chirurgie," Berlin, 1898—3 large volumes. Pagel speaks in the highest terms of the value of this great work, which he describes as a *monumentum aere perennius* to the memory of its able author.

A. H. B.

Gutta Percha.—The inspissated milk-juice of *Palaquium gutta* (Hook. f.) Burck (fam. *Sapotaceæ*). (No longer official in the United States.) This remarkable substance is admitted into the pharmacopœias of most countries on account of the elastic varnish which can be made from it, and of its value in the making of plastic splints in surgery. The plant is a large tree growing, now or formerly, in many parts of Southern Asia, and in the great islands of the Pacific. Gutta percha was first brought into European use in 1842, having been previously employed by the aborigines in the manufacture of knife and weapon handles. From the vicinity of Singapore, where it was previously abundant, from Penang and other accessible places, the tree has been practically exterminated by the wasteful method of collecting its valued product. It still exists, however, in abundance in the Malay peninsula, whence most of the gutta percha now comes, in Borneo, Sumatra, and other places. The method of collection is as follows: The trees are felled and the bark is stripped off, when the milky product beneath it collects upon the surface of the wood, and is scraped off and put into a hollow leaf or other convenient receptacle. This juice quickly coagulates upon exposure to the air, and the putty-like curd is moulded while yet soft into blocks or cakes of various sizes and shapes. It is of a light or medium brown color, often gray upon the surface, sometimes, when nearly pure, white or ash-colored, of a peculiar rubber-like odor, and a rather flexible consistence at common temperatures. At something above 120° F. it becomes very plastic, and may be moulded into any shape and welded, resuming its hardness upon cooling. Ordinary gutta percha is an impure substance, containing inevitably, by the method of its collection, a considerable amount of coarse admixture of vegetable tissue, chips, etc., besides the residues of the evaporation of portions of the liquid juice, imperfectly separated from it in coagulating. It is soluble in chloroform, turpentine, carbon disulphide, etc., but not in water, alcohol, acids, or alkalies. Its purification may be effected by solution in one of the above, or by mixing with hot water and straining. The sheets, in which form it is generally sold for surgical use, are made by rolling it while hot between cylinders.

The principal portion, seventy-five per cent. or so,

of good gutta percha, consists of an amorphous white mass or powder having the general properties given above, named *gutta*. It contains, further, from fourteen to sixteen per cent. of *alban*, a light flaky powder soluble in boiling alcohol, and from four to six and a half of *fluavil*, which is rather more soluble than either of the above (Payen).

Gutta percha is employed in medicine only on account of its physical properties. A nine-per-cent. solution of it in chloroform, with ten parts of carbonate of lead added mechanically to carry down coloring matters and impurities, is an excellent protective varnish for abrasions, excoriations, and small wounds, to be used in the same way as collodion. In sheets, from one-eighth to one-fourth of an inch thick, it is to be had of the instrument makers as a splint material. For cases in which there is a good deal of irregularity of surface to be fitted, as in fractures of the jaw, the bones of the thumb or great toe, or the metacarpal or tarsal bones, it is very useful; also in making splints that must often be taken off and reapplied. The form of the splint should be cut about one-fourth larger each way than the desired splint, as it shrivels when softened and when thrown into water at a temperature of about 130° or 140° F. or more. The limb having been prepared by adjusting the parts, shaving, bandaging, etc., as required, the softened splint is laid on the part and quickly moulded by the fingers to the desired form. A bandage where necessary is then applied, and cold water poured over all. When hardened the gutta-percha splint may be taken off, trimmed, and permanently reapplied. If it is desired to piece or weld the gutta-percha, it should be softened by dry heat, as over a lamp or gas. The fingers may be wet while handling it. Its use in submarine cables and other electrical apparatus is very extensive. H. H. Rusby.

Guy de Chauliac.—"The most celebrated surgeon of the Middle Ages, and the father of French surgery." (Dezeimeris.) He was born, as his name indicates, in the village of Chauliac, southeastern France, about the year 1300. He received his preliminary education in the College connected with the cathedral of Mende, a school that was quite famous in those days. He first studied medicine at the University of Montpellier, and then crossed over into Italy, in order to enjoy the privilege of being taught by Bertrucius, who alone among the medical teachers of that period gave instruction directly from the human cadaver. At Montpellier, France, for example, human anatomy was probably not taught in this manner until 1490. On the other hand, it is an established fact that in Italy the dissection of human bodies was practised as early as during the first decade of the fourteenth century, Mondini having dissected the body of one woman in 1306 and the bodies of two others in 1315.

Guy de Chauliac practised medicine in several different cities, probably for a longer period in Lyons than anywhere else. About 1348 he entered the service of Pope Clement VI., at Avignon, to which city the papal seat had been transferred in 1309. He published his celebrated treatise on surgery in 1363. It has not yet been satisfactorily determined in what language Guy de Chauliac originally wrote this book. Three different manuscripts are in existence—one in Latin, one in French, and one in the language of Languedoc, the author's native tongue. He died in 1370.

Up to 1890 the most modern edition of Guy de Chauliac's treatise, so far as I am able to learn, was that printed at Lyons in 1659, but at the date first mentioned Edouard Nicaise published at Paris, in old-style French, a beautiful edition of this remarkable book. On turning over its pages in a casual manner I discovered a section devoted to fractures of the thigh, and was much surprised to find that Guy de Chauliac's method of treating this injury was almost identical with that which is practised by surgeons of the present day. The paragraph to which I refer occurs on page 368 of Nicaise's version. It reads, when rendered into English, as follows: "As to my practice it is this: I apply to the thigh of the fractured limb long splints that extend down to the foot, and I reinforce these appliances sometimes with supports made of straw, sometimes with a casing. I attach a weight of lead to the foot, using for this purpose a cord which passes over a small pulley; and in this way I cause the limb to be held firmly and continuously in a state of complete extension. If it is found then that the two limbs are not of equal length, a little pulling from time to time will overcome the inequality. It is well every nine days to move the parts a little, and to continue this practice for some time afterward. Firm union may be looked for at the end of fifty days." A. H. B.

Gymnamœbida.—The order of protozoans which includes the genera of parasitic amebas—*Entamœba*, *Paramœba*, etc. See *Protozoa*. A. S. P.

Gymnastics.—See *Exercise*.

Gynæcophorus.—A synonym of *Schistosomum*, a genus of round-worms. These animals are dicœcious and the male carries the female on a groove on his ventral surface. They are blood parasites and the three species, *S. hæmatobium*, *S. mansoni*, and *S. japonicum*, cause various types of schistosomiasis. See *Nematoda*. A. S. P.

Gynecological Examinations. — History. — A proper history is a necessary preface to the diagnosis of every gynecological case. It should not of necessity be lengthy, but certain facts in the life history of the patient, peculiar to her sex, which may have an especial bearing upon the condition of the female organs, should be carefully inquired into.

We will pass over the points common to all histories and simply emphasize those having a gynecological bearing. The menstrual history should be thoroughly ascertained. The age at which the menses first appeared; the duration of the flow; the quantity and character; if accompanied by pain, whether it develops before, during, or after the flow; and its location, whether in the uterus or the region of the appendages, or in the sacrum; the regularity of the periods; the date of the last menstruation; and, finally, the history of the menopause—these are all subjects for inquiry.

In judging the condition of the menstruation as to duration, quantity, and regularity, it is well to remember that in this respect every woman is a law unto herself, and she must therefore be judged according to her own standard. But, her habit in this respect having once been established, she should not deviate from it.

The history of her pregnancies should be thoroughly investigated, as about two-thirds of all patients coming to the gynecologist can trace their sufferings from a miscarriage, a difficult labor, or an abnormal puerperium.

Pain in some form or other is the most prominent gynecological symptom, and is usually responsible for the patient's seeking the aid of her physician. The pain may be in the form of headache, backache, pelvic tenesmus, or a sensation of bearing down; or it may be referred to some particular part of the pelvis. Its character and location should be carefully ascertained. The condition of the bowels is a very important point for inquiry, as so many of the troubles in this class of patients are due to pelvic congestion induced by chronic constipation and irregular habits of going to stool.

Any bladder symptoms should be noted, especially burning or pain on micturition and frequency of the act, as they may be an indication of gonorrhea, a disease which is now recognized as one of the most potent factors in the etiology of gynecological cases.

The character, quantity, etc., of any discharge should be determined.

Finally, the presence of those symptoms known as neuroses, of a reflex character, should be recognized.

For the details of more extended history-taking the reader is referred to such works as those of Kelly,

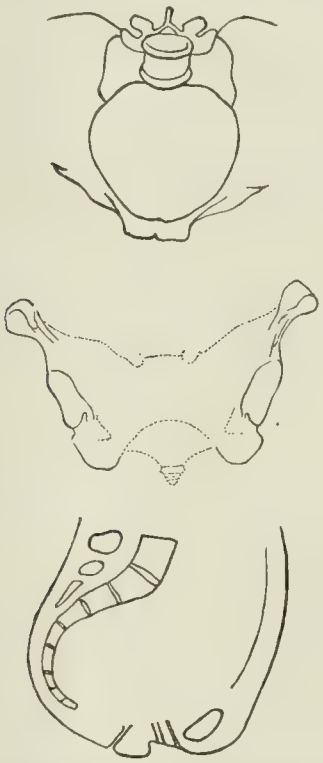

Fig. 2894.—Outline Diagrams for Recording Displacements, Growths, etc., in History-taking.

Montgomery, Webster, Hirst, Ashton, etc. For ready reference, speed, and accuracy, we believe that cards or loose leaves for use in one of the modern filing systems and used in conjunction with outline diagrams of the various pelvic planes, in which it is possible graphically to note the size, situation, and shape of growths, displacements, etc., is of especial value in recording gynecological cases. Rubber stamps of diagrams of the pelvis and abdomen are obtainable. (See Fig. 2894.) Whatever system of history-taking is adopted it should be strictly adhered to, as routine habits will undoubtedly guard against error.

The novice will do well to remember, if he wishes to avoid embarrassment both to himself and to his patient, that all subjects of a delicate nature should be approached in an open, frank manner, devoid of subterfuge or insinuations of any kind, and coupled with the kindness and dignity of manner befitting a gentleman.

That the patient will submit to an examination should be taken as a matter of course, as at the present day most women know that such a procedure is a necessity and are prepared accordingly.

Anesthesia.—In virgins it is desirable when possible to examine under anesthesia, for as a rule, a first examination of such patients is very unsatisfactory, and therefore productive of no positive diagnosis. Nitrous oxide is an ideal anesthetic for such a case.

If it is possible to avoid it, a vaginal examination should not be made in *virgines intactæ*. In the majority of cases a rectal examination will answer all purposes. The method of rectoabdominal palpation to be used will be described later.

Not infrequently in married women, if there happens to be an unusual rigidity of the abdominal muscles, a superabundance of fat, or a neurotic patient it is desirable to employ an anesthetic, especially, when the advisability of an operation is dependent upon an accurate diagnosis. When an examination is decided upon it should always be carried out in a thorough manner, and this necessitates that a systematic plan of procedure should be followed.

Nurse.—Whenever possible, a third party should be present, not only for the comfort of the patient, but as a protection to the physician from the malicious charges which are by no means uncommon. If the physician can have a nurse at his disposal, this plan is by far the best, as the ready assistance and soothing influence of a trained female assistant go far toward rendering the ordeal less trying to the patient, and enable the physician to conduct his examination with much greater facility. When a nurse is not available, a female friend brought with the patient may often be of great assistance in holding a speculum, etc., but there will be many occasions when the general practitioner will have to conduct his examination unaided. While an assistant is certainly desirable, she is by no means indispensable.

Table.—The question as to what is the best table for gynecological examinations is one that is often asked by the novice. The simpler the table the better. A costly complicated table or chair is not at all necessary, and a great many gynecologists work with one of the simplest construction. An ordinary solid table, four feet long, two feet wide, and two and one-half to three feet high, will answer for all ordinary purposes. The foot of the table should be raised about two inches, and should be fitted with foot-rests. An extension arm or leaf attached to the right-hand corner is of great utility when employing Sims' position, as it allows the legs and feet of the patient to have a proper support, when the buttocks are drawn to the edge of the table.

A valuable adjunct, in the writer's opinion, is a pair of Edebohls' leg-holders. They consist of two perpendicular rods that are attached to the corners of the table and have slings at their upper ends. The feet being fastened in the slings, are elevated to such an extent that the thighs are flexed upon the abdomen and rotated outward. This insures the greatest amount of relaxation of the abdominal muscles, and successfully prevents the approximation of the patient's knees. It is therefore of especial value in nervous patients.

Placing the Patient upon the Table.—If a nurse is not available, the physician should understand how properly to place the patient upon the table, so that he may not appear awkward or render the ordeal unnecessarily embarrassing. A screen should always be at hand, behind which the patient is instructed to retire in order to loosen all tight clothing about her waist, and especially to unfasten her corsets.

In all cases the patient should empty her bladder before going on the table. This is a detail that is frequently neglected, and it is the cause of an unsatisfactory examination in many instances. It is likewise of advantage that the lower bowel should be emptied, and when possible the patient should be instructed to take an enema before coming to the physician's office. The patient should be first placed in the dorsal position to permit of the bimanual examination. A stool or chair is placed at the foot of the table and the patient is directed to stand upon it, while the physi-

cian holds up a sheet between the patient and himself. She is then instructed to lift up all her skirts behind and sit down upon the edge of the table. She next lies down and the sheet is thrown over her, while her feet are adjusted in the foot-rests. The folds of the sheet are then wrapped about each leg so that there is no part exposed but the vulva.

The Examination.—The examination for purposes of diagnosis should consist of two parts—the first without instruments, and the second with instruments. It may be possible to arrive at a diagnosis by the bimanual touch alone, but an examination confined to

Fig. 2895.—Method of Separating the Labia for Inspection of External Genitals.

this procedure cannot be considered thorough or complete; an actual inspection of the cervix, and an exploration of the uterine cavity are in many cases indispensable if an accurate opinion is to be given as to the conditions present.

The Examination without Instruments.—This should be conducted systematically. A good plan is to investigate the parts from without inward, commencing with the external genitals; then the vagina, cervix, uterus, ligaments, the appendages and the pelvic cavity are examined in order.

The Inspection.—This is an extremely important part of the examination, and it is too frequently omitted.

The labia majora are separated with the fingers of both hands, and the hood of the clitoris is retracted, so as to reveal any adhesions or retained concretions which may be the cause of irritation sufficient to produce neurotic disturbances. The meatus urinarius is examined for caruncle, prolapse of urethral mucous membrane, or urethritis. Skene's glands are to be observed for evidences of inflammation and discharge. These glands are very often the site of a latent gonorrhea which would be overlooked unless they were carefully examined. The presence of a discharge in the urethra or from Skene's glands can best be determined by "milking" the anterior vaginal wall with the palmar surface of the index finger. A suspicious discharge should be stained for gonococci.

Prolapsus of the anterior and posterior vaginal walls (cystocele and rectocele) and procidentia uteri should be looked for, and so also should varicose veins of the vulva which are the result of some obstruction to the circulation and may be indicative of a tumor or growth blocking the pelvis.

The amount of prolapsus can be best judged by getting the patient to strain or bear down as if at stool, while the examiner's fingers separate the labia. This method shows the degree of relaxation of the vulvar outlet and the amount of supporting power of the pelvic-floor muscles. Injuries to the levator fibers and the pelvic fascia are thus accentuated. The degree of laceration of the perineum should never be estimated by a superficial inspection, as there may be an ample cutaneous covering, but with no body back of it. If the body of the perineum be grasped between the thumb and forefinger, after the latter has first been introduced into the rectum, the amount of muscular structure can be readily determined.

Bartholin's glands should always be examined for evidences of inflammation, which is frequently gonorrheal in character. Latent gonorrhea will be discovered by the careful examiner in the vicinity of these glands in a surprising number of cases. Normally the mouths of the ducts, which are situated on each side of the labia majora just below the center, and usually behind a tag or ear of the remains of the hymen, are of the same color as the surrounding mucous membrane. The normal secretion which can be expressed from them is a glairy, colorless fluid like white of egg. Whenever the mouths of the glands seem to be much darker in color and to be eroded, suspicion should at once be aroused. If gonorrhea is still present, the secretion expressed from the glands will be found to be turbid or purulent, and, if careful search is made, gonococci will usually be found. In such a case the gland itself can be felt between the thumb and finger to be decidedly enlarged and sometimes tender.

The anus and rectum should be searched for hemorrhoids, fissure, fistula, etc. The rectal mucous membrane can be readily everted by the finger placed within the vagina.

Any inflammatory condition of the vulvovaginal mucous membrane, if associated with copious purulent discharge, can hardly escape the notice of the careful observer, who will recognize it as a specific infection. Likewise the presence of condylomata, chancroids, venereal warts, etc., will readily be detected. It should always be borne in mind that an innocent wife is frequently a sufferer from diseases of this class through no fault of her own, and in utter ignorance of their nature.

The Bimanual Touch.—After completing the inspection, the physician will next lubricate the examining fingers with some lubricant, as liquid soap, glycerin, or lubrichondrin. (The advantage of the latter is, that it is readily soluble in water, so that the hands can be speedily cleansed after they have been smeared with it.)

The examiner should accustom himself to the use of the fingers of either hand in the vagina, as it is easier to reach the left appendage with the left hand, and the right one with the right hand.

At first it is best to use the index finger alone in the vagina. In introducing the fingers, they should be first flexed and the vulvar opening approached by sweeping the knuckles of the flexed fingers over the perineum from below, until the *knuckles* slip into the vaginal orifice, then the fingers are straightened until they find their way over the perineum into the vagina. By the employment of this method it will be possible to avoid touching the clitoris, urethra, and vestibule with the tips of the fingers, and should the circumstances of the case not permit of an inspection (as in an emergency examination, with the patient in bed), the entrance to the vagina can always be found with the greatest ease and without causing any pain or distress whatever to the patient.

It is important that the fingers should be held in a manner that will insure deep penetration into the pelvic cavity. The hand must be rendered as narrow as possible to permit its passage between the ischial tuberosi-

ties. When this is accomplished the whole pelvic floor can be pushed up or invaginated so as greatly to increase the penetration of the examing fingers, and thus render accessible to the touch parts which cannot otherwise be reached.

The vaginal, or passive hand, with its forearm muscles, should be in a state of relaxation. Two fingers in the vagina (the index and middle) will give the best results, and should always be employed where the size of the entrance will admit them without injury. The thumb should be held straight up, and the ring and little fingers should be flexed at the *proximal phalangeo-phalangeal* joints (see Fig. 2896), and *not* at the metacarpophalangeal articulations, as is usual. The rea sons for this will be apparent if the illustration (Fig. 2897) is consulted. *A* shows the ring and little fingers tightly flexed into the palm of the hand in the usual way. The full length of the third phalanx of the ring finger and the head of the metacarpal bone is brought broadside or across the pubic arch, the ends impinging upon the tubera-ischii and the rami of the arch, thus making deep penetration impossible, as bone rests against bone. *B* shows the correct position of the fingers. Note how narrow the hand is with the fingers in this position, allowing them to slip easily between the tubera-ischii and to push up ahead of them soft and yielding pelvic floor structures, thus invaginating these soft tissues, into the pelvic outlet. By this maneuver, at least an inch can be added to the reach.

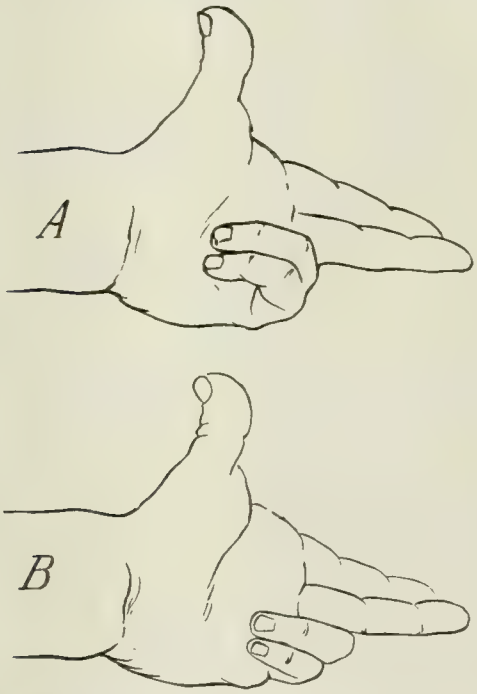

Fig. 2896.—Position of Fingers for Vaginal Examination. A, Incorrect, B, correct, methods of flexing the fingers.

The elbow of the examining hand should rest against the examiner's hip, and all pressure should be made by throwing the weight of the body upon the elbow, thus allowing the muscles of the forearm and arm to be at rest, which greatly facilitates the vaginal touch. After the fingers have gained entrance into the vagina, the size, thickness, and sensitiveness of the organ are to be noted. The mucous membrane may present a smooth, velvety feel as when the rugæ are obliterated, or it may feel harsh and granular as in certain forms of vaginitis. Spasm of the vagina (vaginismus) may be observed as the fingers pass the introitus. As the fingers pass on toward the upper portion of the vagina, they should convey to the examiner a knowledge of the direction of the canal, of any abnormal relaxation of its walls, and of the presence of cysts or other abnormal growths. The presence or absence of fecal matter in the rectum can be readily made out with the finger in the vagina. Sometimes hard scybalous masses may be mistaken for an abnormal growth

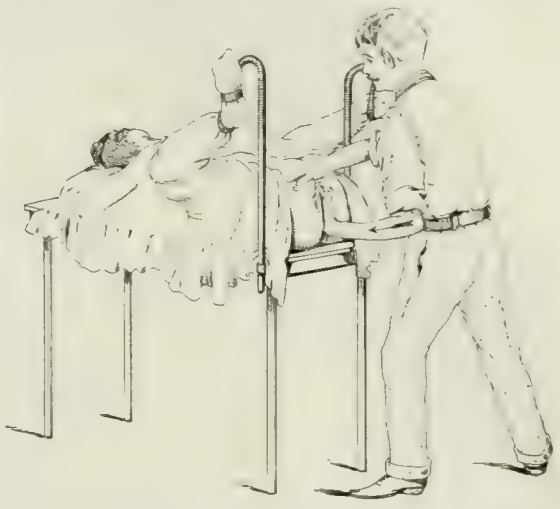

Fig. 2897.—Bimanual Examination, with the Patient on the Table.

by a careless observer, but they can usually be indented on pressure. However, if there is any doubt, an enema will promptly clear up the diagnosis. As soon as the cervix has been reached, the fingers should be rotated until their palmar surfaces are directed upward, and their tips should be slipped under the cervix until that organ rests upon them. The relation that the cervix bears to the axis of the vagina should be accurately noted. When the uterus is in its normal position, its axis is approximately at right angles to the axis of the vagina. Therefore the tip of the examining finger should touch the anterior wall of the cervix as it reaches the upper portion of the vagina. Should the examining finger directly enter the mouth of the cervix, it would be an indication that the uterus was displaced backward (retroverted), and that, therefore, the axis of that organ was parallel, or continuous, with the vaginal axis—unless further examination showed that the body of the uterus was flexed upon the cervix. In cases of extreme retrodisplacement, the cervix would be found to be pointing upward toward the symphysis, and the entering finger would encounter the posterior cervical wall (see Fig. 2898.)

In anteversion the cervix will be found to point backward, its axis forming an acute angle with the axis of the vagina.

It must be borne in mind that the position of the uterus can be greatly influenced by the amount of urine in the bladder. A full bladder will throw the uterus into a position of retroversion of the first degree. Errors will be avoided if the precaution is taken to have the bladder emptied before the examination.

The condition of the cervix itself can readily be determined by the sense of touch. The number, extent, and location of lacerations (if any are present) should be noted. It is important also to determine the degree of patulency of the os, and whether any granular erosion or carcinomatous induration exists. The presence of dense scar tissue in the angles of lacerations should be felt for, and the effort should be

made to ascertain whether there is any hyperplasia of the cervix or any cystic degeneration of the Nabothian glands. Cysts of the glands of the cervix give to the touch the impression of the presence of buckshot under the mucous membrane.

The normal position of the cervix in the vagina is usually at a point corresponding to about the junction of the upper and middle thirds, and ordinarily it is not difficult to reach. In some cases, when there is a very deep vagina, or when the pelvic muscles are rigid and unyielding, it may be difficult to reach the cervix. It is a good plan to place the external hand gently upon the lower abdomen in commencing the examination; then, if the cervix cannot be readily

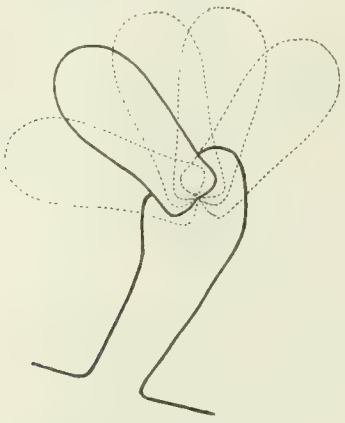

Fig. 2898.—The Relation of the Uterus to the Vaginal Axis in the Different Displacements.

reached, gentle pressure should be exerted in the direction of the axis of the pelvic inlet. This will depress the uterus and bring it within touch of the fingers in the vagina.

If the uterus is prolapsed, the cervix will naturally be found nearer the vulva than is normal. Care must be taken to differentiate a prolapsus of the uterus from an elongated or hypertrophied cervix.

After the examination of the cervix as above described, the next step will be to examine the uterus as a whole. The knowledge obtained by the simple vaginal touch of the cervix must be further amplified by the bimanual touch, if one wishes to arrive at a complete diagnosis of the position and condition of the uterus. It is obvious that if a flexion of the uterus exists, the position of the fundus as indicated by the relation of the cervix to the vaginal axis, will be incorrect.

In commencing the bimanual examination the physician should pass the tips of the vaginal fingers under the cervix, so that it shall rest upon their palmar surfaces. The external hand rests upon the abdomen midway between the symphysis and the umbilicus, ready to make counterpressure from above.

The management of the external hand is a very important matter. Too vigorous pressure is the rule with the novice, and it will promptly insure failure. Such a procedure will cause the patient to resist to the utmost the rude invasion, by contracting her abdominal and pelvic muscles instead of cooperating with the examiner by relaxing them. It is therefore well to bear in mind, from the very beginning, that in the majority of cases more can be accomplished by gentleness of manipulation and skill, than by physical force. When it is necessary to use deep pressure, it must be done slowly and gradually, so as not to alarm the patient. By the exercise of strategy in distracting the patient's mind from the examination, as by asking questions and by getting her to take deep inspirations, we shall be able to seize the moment when the abdominal muscles are relaxed and gain the desired entrance into the pelvis with the external hand.

The four fingers of the external hand should always be kept close together, and the palmar surfaces of the fingers should be used as much as possible and not the tips. To separate the fingers and to use the tips is decidedly unpleasant to the patient, and will cause her to resist.

The first object of the bimanual examination should be to get the uterus between the two hands, so that it can be palpated. With the cervix resting upon the fingers in the vagina, slight upward pressure in the direction of the inlet of the pelvis is made, while the external hand makes gentle counterpressure from above, gradually increasing until the fundus of the uterus is reached. This can be told by the fact that the pressure on the fundus is at once communicated to the fingers in the vagina, upon which rests the cervix (see Fig. 2899).

While holding the uterus in this manner, the size, shape, consistency, and sensibility of the organ can be judged, and also the amount of mobility that it possesses. The uterus should normally give the impression of being suspended between elastic ligaments. It is movable forward or backward, upward or downward, in response to moderate pressure. On the pressure being removed, the organ should promptly regain its normal position. In examining for the mobility of the uterus in this way, valuable knowledge can be gained as to the presence or absence of adhesions, or of infiltration of the vaginal vault or broad ligaments, which would cause various degrees of fixation of the uterus.

The size of the uterus can be judged after a little practice, as one soon learns the impression that the normal uterus conveys.

Fig. 2899.—Locating the Fundus and Cervix by the Bimanual Method.

Any irregularity on the surface of the fundus uteri, such as might be caused by fibroids or malignant growths, may be determined by the external hand.

The various positions that the uterus may assume must be diagnosed by comparing the relation that the cervix bears to the vaginal axis, and the position that the fundus occupies as determined by the external hand.

If the cervix is at right angles to the vagina, and the external hand discovers the fundus about midway between the umbilicus and the symphysis, the position of the uterus is normal.

Should the uterus be anteverted or anteflexed, it would be necessary to explore with the external hand right up to and behind the symphysis, until the fundus had been located. The position of the cervix would indicate whether the uterus was anteverted or anteflexed, and this could be further confirmed by slipping the vaginal fingers in front of the cervix, when with the external hand on the fundus any sulcus or bend in the organ could be easily appreciated.

Fig. 2900.—Recto-abdominal Palpation while Drawing Down a Retrodisplaced Uterus with Kelly's Corrugated Tenaculum.

Three varieties of anteflexion may be recognized. The body of the uterus may be in its normal relation with the pelvis, while the cervix is bent so as to lie in the axis of the vagina, instead of at right angles to it. This is spoken of as anteflexion of the cervix. The opposite of this condition may exist, the cervix being in its proper position, while the body is bent forward upon the cervix. This variety is designated as anteflexion of the body, in contradistinction to the above. Then again the third variety may occur, in which both cervix and body are out of their normal positions, the flexion being very acute, and the cervix and body closely approaching each other.

When the uterus is displaced or flexed backward, the search for the fundus is made toward the sacral promontory. It is apparent that if the fundus is at or below the level of the promontory, it will be found extremely difficult—unless there is unusual relaxation of the abdominal muscles, or unless we employ a general anesthetic—to get the uterus between the hands; indeed, in some cases, it is simply impossible to accomplish this.

The fact that the fundus could not be found, and that the cervix was pointing in the axis of the vagina, would be strong presumptive evidence that there was a backward displacement of the organ beyond the sacral promontory.

Retroversion is classified by most authors into three degrees: When the fundus points toward the sacral promontory, it is a retroversion of the first degree. If it points into the hollow of the sacrum, being practically continuous with the vaginal axis, it is the second degree. When the fundus is still lower in the pelvis, and the cervix begins to point upward toward the symphysis, it is classified as the third degree. (See Fig. 2898.) In the second and third degrees of retroversion, it is often impossible to reach the fundus with the external hand by the ordinary method of examining. In such cases the difficulty may be overcome if the uterus be drawn down by a tenaculum, until the cervix is nearly at the site of the hymen. If the index finger be inserted into the rectum while the uterus is drawn down it is frequently possible to palpate the body and fundus with great facility. Kelly's corrugated tenaculum is designed especially for this purpose, as it enables the examiner firmly to hold the tenaculum with the external fingers of the lower hand, while the counterpressure is made as usual with the upper hand on the abdomen (see Fig. 2900). This method enables the examiner to reach the fundus with both hands.

In all cases of retrodisplacement it is important to determine whether the uterus is adherent or not as the necessity for an operation may be dependent upon that condition. If the uterus is easily replaceable to its normal position it is reasonable evidence that it is not bound down by adhesions, therefore the mobility of the uterus must be studied. The employment of the knee-chest position is here of great value as a strong vacuum is produced in the pelvis by reason of the intestines gravitating toward the diaphragm, and if the perineum is retracted with a speculum the vagina will distend with air and the uterus if moveable will assume its normal relation as the fundus will become dependent. This maneuver also gives the best exposure for an inspection of the vaginal walls and cervix. (See Fig. 2901.)

Retroflexion of the uterus can be differentiated from retroversion by the presence of a distinct sulcus or angle being felt at the junction of the cervix with the body. When a sulcus cannot be felt, and the fundus is out of reach of the finger in the posterior vaginal fornix, it is to be inferred that the uterus is not retroflexed. The afore-mentioned method of drawing down the uterus will permit this point to be accurately determined, unless adhesions prevent, in which case the diagnosis must be left until it can be settled by the uterine sound or probe.

It is wise always to confirm a diagnosis of flexion by the sound, as a subperitoneal fibroid on either the anterior or the posterior uterine wall will frequently be a cause of deception.

Fig. 2901.—Knee-chest Position.

Lateral displacement of the uterus to the right or left of the median line should be carefully noted. A uterus in such a position has either been drawn over to one side by the contraction of adhesions, or it is pushed over by the presence of a cyst or growth filling the opposite side of the pelvis.

Normally the pelvic organs, with the exception of the ovaries, are not sensitive to ordinary palpation. Deep pressure upon these organs will cause a nauseating pain, accompanied with faintness, similar to that produced by pressure upon the testicles. Tenderness

of the uterus will generally indicate disease of that organ, as endometritis or metritis, although there is a certain class of patients whose organs, even when not appreciably diseased, manifest an abnormal degree of hyperesthesia. Pelvic sensitiveness is one of the prominent symptoms of an hysterical patient.

One of the most important items of information to be derived from the examination is the consistency of the uterus and the surrounding structures, as determined by the sense of touch. Each structure has its own standard, and the examiner must first become thoroughly familiar with the normal consistency before he can appreciate deviations which indicate pathological changes. The soft, friable condition of a carcinomatous cervix, the boggy impression conveyed by a subinvoluted or edematous uterus, the hard plaster-of-Paris-like feel of the vaginal vault in pelvic peritonitis, the fluctuating sensation of a fluid tumor or abscess, are but a few of the conditions which must depend upon a comparison with the normal for their diagnosis.

After the examination of the uterus has been completed, the attention should next be directed to the ligaments which aid in its support. These ligaments are prone to inflammatory thickening, which may give rise to pain, and which frequently interferes with the normal mobility of the organs.

The anterior posterior, and lateral fornices of the vagina are to be palpated to ascertain the condition of the uterovesical, uterosacral, and broad ligaments. Normally the vaginal vault is elastic to the touch, and should induration and thickening of the ligaments be present, these conditions can usually be made out by palpation.

The vaginal fornices must be carefully explored by bimanual touch, for the presence of cysts, growths, prolapsed ovaries, collections of fluid, etc., which may occupy the cul-de-sac of Douglas or the uterovesical space.

By comparing one lateral fornix with the other, as regards the ease with which the examining fingers may be moved in different directions, and also by comparing the two sides as regards the degree of pain elicited by pressure, one may obtain considerable information in regard to the pathological conditions that may be present.

It is not possible in a limited article like the present one to do more than hint at the diagnosis of the many complicated conditions which will be found in examinations of the vaginal fornices. It is hardly necessary to say that years of experience may be required before it is possible for one to acquire the *tactus eruditus* necessary to ascertain, by digital exploration, the pathological conditions that are present in the pelvic cavity in any given case. The most expert gynecologists not infrequently see, on opening the abdomen, that their diagnosis was at fault. A thorough appreciation of the normal condition of the parts will enable the novice more readily to recognize pathological deviations, and especially is this true of the uterine appendages. It is a frequent occurrence, in the writer's experience, to come across men, in active general practice, who state that the palpation of the uterine appendages is a closed book to them. Diagnosis of diseases of these important organs is entirely beyond their reach for the reason that they cannot feel the adnexa, although they repeatedly examine cases in their practice. They can often make a diagnosis as to the position of the uterus, the condition of the cervix, or the pelvic floor, but the condition of the ovary and tube is like the "will-o'-the-wisp"; it easily evades the simpler methods of examination.

In examining the ovaries and tubes, the novice will frequently attribute his failures to the shortness of his phalanges, and he will endeavor by pure physical force to gain further entrance into the pelvis, with the result that he causes needless pain to the suffering patient. As she is frightened by fears of worse pain to come, she sets to the utmost her abdominal and pelvic-floor muscles, in order to resist the rude invasion with which she is threatened, and thereby makes it impossible for the examiner to get within reach of the adnexa with his examining fingers. The novice usually has no definite plan of procedure in his mind, and his one idea as to the position of the ovary is, that it lies on one side of the uterus at or near the plane of the fundus, just as he has seen it pictured so often in his text-books.

In order to command success, there are three important factors in the problem that the examiner must thoroughly understand.

The first of these factors with which we must reckon is the abdominal muscles. These abdominal muscles form the armor which protect the abdominal viscera from injury, and when they are in a state of rigidity—as occurs almost instinctively, although they are under the control of the will, whenever the contents of the abdomen are in danger of trauma—they offer such a strong barrier that it is impossible for the examiner to palpate the underlying organs through them.

Unless the patient's musculature has become so attenuated by poor physical condition and consequent emaciation, as often results from too frequent childbearing or some wasting disease, one might as well attempt to palpate the pelvic structures through a wooden board as through the rigid recti. Overcoming this obstruction to success, then, is dependent on either cooperation on the part of the patient, or anesthesia.

The second factor in the problem is to appreciate that the ovary and tube are movable. They have a considerable range of mobility, extending from behind the uterus in the median line of the body to the lateral wall of the pelvis. This can well be brought to the examiner's mind when he remembers how he has observed the surgeon bring up the appendage out of the true pelvis upon the abdomen of the patient through the abdominal incision.

The third factor is that these organs are extremely slippery bodies, as will be appreciated by the novice when he attempts to deliver an ovary through the abdominal incision. It is about like picking up an eel out of a basket of eels, and until he learns the trick of straddling the broad ligament with his fingers, and then hooking up the ovary with them, he will not succeed.

In conducting a bimanual examination, certain essential preliminaries must be observed. They are that all constricting clothing about the abdomen and waist line must be loosened or removed, and that the bladder must be emptied immediately before the patient is placed upon the table. This latter essential is the one that is most frequently overlooked by the general practitioner, and yet how can we possibly expect to palpate the adnexa or judge of the position of the uterus with a bag containing half a pint or more of fluid interposed between the examining fingers.

It is essential, to start with, to have the fact firmly impressed on our minds that more can be accomplished by gentleness of manipulation and tact than by physical force, thus obtaining the cooperation of the patient and eliminating the resistance of the abdominal muscles. When it is necessary to use deep pressure, it must be done slowly and gradually—so as not to alarm the patient—and by the exercise of strategy in distracting the patient's mind from the examination by asking questions—especially questions that will cause her to think before answering, as, for instance, the exact date of such and such an occurrence; also by getting her to take deep inspirations with the mouth open. We seize the moment when the abdominal muscles are relaxed to gain the desired access into the pelvis with the external hand.

The examiner should accustom himself to use the fingers of either hand in the vagina, as it is easier to reach the left appendage with the left hand, and the

right one with the right hand. But, as a rule, one gets accustomed to using the same hand for the vaginal work all the time. The majority of gynecologists prefer to use the left hand in the vagina and the right hand on the abdomen, especially when they are right-handed.

The first step necessary to the palpation of the adnexa is to locate the fundus of the uterus, as with the fundus as a guide the location of the appendages is made easier. This is done after the manner previously described and shown in Fig. 2899. Having located the cervix and the fundus of the uterus, the next step is to remember that the tube and ovary, unless bound down by adhesions, are *movable* and *slippery*, therefore the examiner must endeavor to *catch* these organs, and as they may lie or be pushed into any part of the space between the middle line of the body and the lateral pelvic wall, he must systematically search each half of the pelvis. To accomplish this, the vaginal fingers are next slipped to one side of the cervix into the lateral fornix, and deep penetration is made in a direction upward and backward, at a point midway between the cervix and the pelvic wall. These fingers remain somewhat stationary, while the four fingers of the external hand, curved in the shape of a scoop, rake the area from the fundus to the vaginal fingers. This maneuver will cause the slippery ovary to glide away from the uterus outward toward the lateral pelvic wall. This procedure is then repeated, as shown in Fig. 2902. Commencing each time a little nearer to the side wall of the pelvis, thus driving the ovary still further outward until finally, when it reaches the "end of its rope" as it were, it is *caught* between the examining fingers. It may frequently be necessary to go over the ground repeatedly

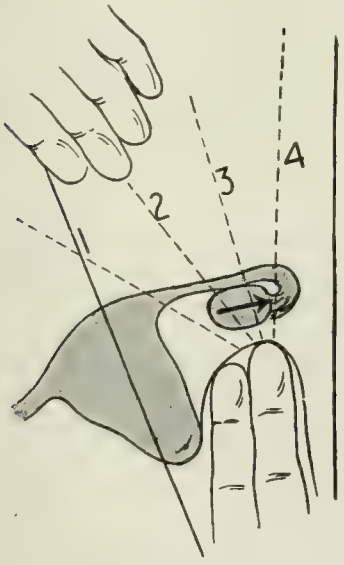

Fig. 2902.—Raking the Area from the Mid Line to the Side Wall of the Pelvis.

before the ovary can be caught, and the position of the vaginal fingers is to be varied from time to time, anteroposteriorly and laterally, so as to cover new planes.

As soon as the ovary and tube are imprisoned between the scoop formed by the external hand above and the fingers in the vagina below (Fig. 2903) their shape, size, sensibility, and consistency can be made out as they slip out between the opposite finger tips. The normal ovary feels about the size of a walnut, and firm pressure gives to the patient the same sickening sensation and pain as pressure of the testicle. After the ovary has slipped through the fingers, the finger tips are still kept together and drawn upwards when the normal tube will be felt in the same way. Extending from the horn of the uterus the tube feels like a cord about the diameter of a slate pencil, and it is not painful to moderate pressure.

The opposite side of the pelvis is to be explored in a similiar manner for the other appendage.

In cases in which this method does not succeed, the examiner should resort to rectoabdominal palpation.

Fig. 2903.—Palpating the Adnexa by the Bimanual Method Catching the appendage between the tips of the opposing fingers

In this method the index-finger is introduced into the rectum instead of into the vagina, and the palpation is made with the opposing hand, as in the bimanual examination just described.

When the uterus is retroverted or retroflexed, rectoabdominal palpation is usually preferable, and is a great gain, especially if the uterus is drawn down to the vaginal outlet by a tenaculum or volsellum, which permits the fundus to be reached posteriorly, and brings the adnexa within the radius of the examining finger (see Fig. 2900). In commencing the practice of bimanual palpation it is wise to select a patient who has borne children, who is thin, and who has relaxed abdominal walls. In women who are fat, and who have rigid abdominal muscles, even the expert must, in many cases, necessarily resort to complete anesthesia before he can make a positive diagnosis. The beginner must not feel discouraged if he fails satisfactorily to feel the adnexa in his first attempts, but by exercising patience and persistence, avoiding haste, paying careful attention to all the minor details, and having a definite plan of procedure in his mind, he will surely attain ultimate success.

The differential diagnosis of the various pathological conditions that may be found about the uterus is such an extensive subject that it can only be touched upon here. In general, fluid accumulations or cystic growths that can be felt through the vaginal vault are diagnosed by the sense of fluctuation and elasticity.

If a mass is diffuse, boggy, ill-defined, immovable, and tender, one would suspect an inflammatory exudate. If a mass gives evidence of fluctuation, of increased heat, and of being very painful when pressed upon, while the patient at the same time gives a history of exposure to infection, of fever, and possibly of chills, the presence of an abscess would be indicated. In inflammatory affections of the tubes and ovaries, these organs frequently are displaced into the cul-de-sac and fixed by adhesions. Generally a hydro- or pyo-

salpinx is of a sausage shape, and can be traced to the uterine cornua.

Whenever the bimanual examination discovers the presence of a large growth, or it is self-evident that the patient has an enlargement of the abdomen, abdominal palpation must be practised. Special works will have to be consulted for the details of the technique necessary. Gentleness of touch is here as essential to success as in the vaginal examination. The novice will do well to avoid giving a positive opinion as to the nature of an abdominal enlargement. Pregnancy, ascites, fat, gas, fecal accumulations, a distended bladder, are but a few of the conditions that must be differentiated from tumors.

Fig. 2904.—Correct Posture of Patient and Nurse in the Sims Position.

When the presence of a growth is certain, not only its character, but also its relations to the pelvic organs must be carefully studied. The presence of adhesions is judged by the amount of fixation that exists. It is a good plan to examine all abdominal enlargements in various postures. Percussion is of value in mapping out the relations of the intestines.

It should be born in mind that in acute inflammatory affections of the pelvic contents, appendicitis and ectopic gestation should be carefully differentiated. At the present time, a gynecological examination can scarcely be considered complete without an investigation of the mobility of the kidneys, stomach, and colon, likewise the habitual posture of the patient on standing, as displacements of pelvic organs are frequently but a part of a condition of general enteroptosis, and sacral backache may belong to the domain of the orthopedist.

Examination with Instruments.—After the bimanual examination has been completed, the instrumental examination is in order.

The instruments necessary are few, and comprise a Sims speculum, a bivalve speculum, a depressor, dressing forceps, single tenaculum, double tenaculum or bullet forceps, probe, sound, and a small flexible spoon curette. A small sterilizer for boiling the instruments is a positive necessity for the protection of the patient from contamination. Immersing the instruments in a carbolic or other solution between examinations is not a safe method and cannot be condemned too strongly. Suitable basins for cleansing solutions, etc., should be at hand, and also an abundance of absorbent cotton. The absorbent cotton should be made into cotton balls, as they are convenient and greatly facilitate the cleansing of the vulva, vagina, etc.

The Speculum.—Of the many varieties of specula that have been devised, there is none better than the original Sims instrument, a description of which can scarcely be necessary. But owing to the necessity of having a nurse or assistant to hold it and the time and trouble necessary to change the position of the patient from the dorsal to the Sims posture, this speculum is not generally used. The bivalve instrument suffices for an inspection of the cervix and vaginal vault and for simple treatments, but if a more thorough and nearer view of the cervix and vaginal walls is necessary for the purpose of investigating the cavity of the uterus or of obtaining a specimen of a suspicious tissue for laboratory examination, the Sims instrument should be employed because by no other method can such a satisfactory examination of the vagina and the cervix be made.

The Sims speculum alone does only a small part of the exposing of the vagina. It is in the Sims posture that the great virtue of this method lies. In the correct Sims position, the pelvis is tilted over at an angle of forty-five degrees, so that the intestines, etc., gravitate out of the pelvic brim, as if out of a basin. This produces a vacuum in the pelvis, and when the speculum retracts the perineum and opens the labia, the air rushes in and balloons the vagina, so that its folds are obliterated, permitting an unobstructed view of the vaginal vault and the cervix. In this position the uterus, unless fixed, can be drawn down nearly to the orifice of the vagina, so that treatment or examination is greatly facilitated.

The bivalve speculum gives but a limited view of the cervix, and affords only a small amount of space in which instrumental manipulations can be carried out. Furthermore, if the uterus is in the normal or in an anteverted position it is sometimes extremely difficult, through this pattern of speculum, to pass a sound or to make intrauterine applications.

A good example of a bivalve speculum is that of Graves (Fig. 2905). It has the advantage of being adjustable at the vaginal orifice, and it can be con-

verted into a Sims speculum. In selecting a bivalve speculum, care should be taken to see that the anterior blade is from a half an inch to an inch shorter than the posterior blade.

The first requisite to a successful examination with the Sims speculum is a proper Sims posture. The

Fig. 2905.—Graves Bivalve Vaginal Speculum.

nurse, or the physician, will direct the patient to sit up on the table and then to lie on her left side with the left arm flexed behind her back. Both knees are then to be drawn up in the direction of the chin, the uppermost knee lying above the under one. In this position the sole of the right foot will lie above the left ankle. The left hand of the nurse should then be passed under the lower buttock until the crest of the ilium can be grasped. Traction should then be made on the crest of the ilium until the lower buttock shall have been drawn to the edge of the table, while at the same time the right hand pushes the upper buttock in the opposite direction. This maneuver will tilt the pelvis so that the brim will lie at an angle of about forty-five degrees with the table. To prove that the pelvis is properly tilted, all that is necessary is to hold a straight rod at right angles to the table and against the lower buttock, when it will be seen that the upper buttock is four or five inches beyond its neighbor. If the clothing has been previously loosened about the lower abdomen and waist, the intestines will gravitate out of the pelvis. The legs and feet should lie on an extension leaf at the right-hand corner of the table. Finally, the patient is covered with a sheet so that only the vulva is exposed (see Fig. 2904).

The physician sits at the foot of the table, and at his right hand there should be a stand upon which the instruments, basins, etc., are arranged within convenient reach. The nurse stands on the physician's left, facing him and close to the side of the table. With her left hand the nurse raises the upper buttock and labium, keeping her fingers separated and extended, and taking care not to use the tips at all, but to roll up the buttock with the palmar surfaces of the fingers only. If the points of the fingers are used like a claw, it is decidedly unpleasant to the patient. The physician draws down the lower buttock and labium with his left hand in a precisely similar manner, while he grasps one end of the speculum with his right hand, being careful to have the index-finger project beyond the bill of the speculum for an inch or more (see Fig. 2906). The speculum and finger should have previously been well lubricated. The idea of the projecting finger is, that it is to enter the vagina in advance of the speculum as a pilot, so as to guide the tip of the instrument behind the cervix.

The direction of the vagina must be borne in mind. As the patient lies in this position, the vagina will run in a direction toward the center of the sacrum. As the finger enters the vagina, the speculum follows after, entering laterally; that is, the flat of the blade corresponds to the direction of the cleft between the labia. As soon as the index-finger feels the cervix, the speculum can be easily guided behind it into the posterior vaginal fornix. The speculum is then rotated to its final position so that it will retract the perineum. The external end of the instrument is given to the nurse, who should grasp it firmly, the fingers surrounding the external blade while the thumb lies in the groove.

The nurse's duties are to hold the speculum exactly as it is given her, and to keep the upper buttock retracted. She can best do this with comfort to herself and satisfaction to the examiner, if she stands straight up, facing slightly away from the physician, so that the arm holding the speculum is wrapped about her body. Her arm is thus steadied, and there is no occasion for any strain on the muscles of the hand or forearm (see Fig. 2904). If she is directed to increase the traction on the instrument, she simply rotates her whole body and does not bring into play the muscles of

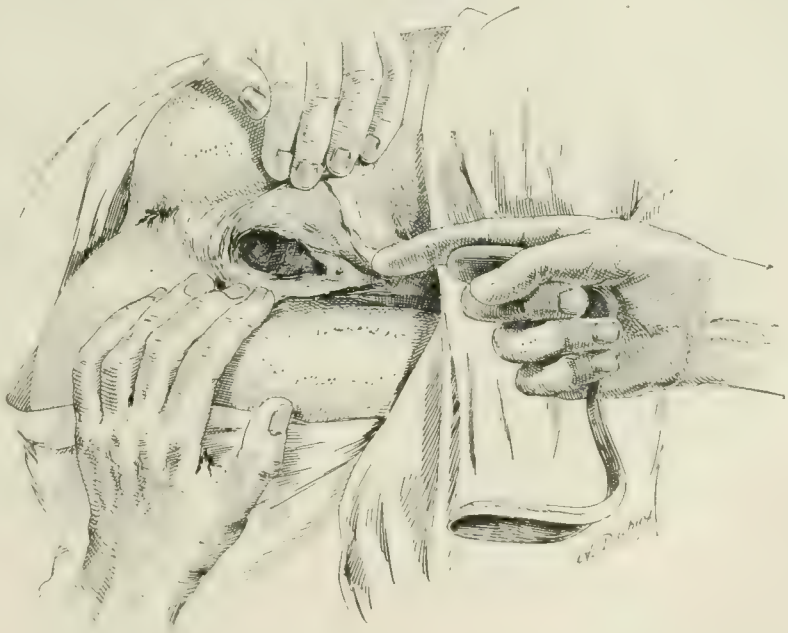

Fig. 2906.—Introducing Sims' Speculum.

her arm. By this method a nurse can hold a speculum for a long period without becoming tired, and it is far more satisfactory than stooping over the patient, grasping the speculum by the shank, and keeping up all the tension with the arm muscles which soon tire and cause unsteadiness.

The Depressor.—As the perineum is retracted and the vaginal walls are exposed to view, the cervix will usually be hidden behind the anterior wall of the vagina, which bulges somewhat in front of it. We should therefore next use an instrument called a depressor, to depress the anterior vaginal wall. The depressor is practically a spatula or spoon (see Fig. 2907), which should be held between the thumb and fingers of the left hand and gently used to push aside the bulging anterior wall so that the cervix may be brought into view. Care should be taken while using this instrument that the wrist of the hand is dropped below the line of vision.

Fig. 2907.—Hunter's Depressor.

The Dressing Forceps.—As soon as the cervix is brought into view a dressing forceps, holding a cotton ball, is used to cleanse the cervix and vagina of any secretion that may be present. Of the different forms of dressing forceps there is a sufficient variety to suit the taste of the examiner. One having a curve is of advantage as it enables the right hand to keep out of the line of vision. Bozeman's forceps is a good illustration of this instrument (see Fig. 2908).

By the inspection of the cervix and the vagina, we are enabled to verify the diagnosis made by vaginal touch. The condition of the vaginal mucous membrane, the presence of fistulæ or of cicatrices, the extent of cervical lacerations, hyperplasia of the cervix, and erosions are all brought into view.

Fig. 2908.—Bozeman's Uterine Dressing Forceps.

The Tenaculum.—The next step is to seize the cervix by the anterior lip, so that it may be drawn down for closer inspection and also for the purpose of steadying the organ while a sound or other instrument is being passed into the uterus. The single-hook tenaculum, as shown in Fig. 2909, is the style of instrument usually employed. It should be hooked into the cervix through the os.

Fig. 2909.—Tenaculum.

For the purposes of examination and of making intrauterine applications, the double tenaculum has many advantages over the single instrument.

No matter how expert the examiner may be, he cannot help making a number of punctures with the single instrument during the course of his examination and treatment. The instrument cannot be left on the cervix, but must be held by one hand, so that if both hands are needed during the preparation of an applicator, etc., the instrument must be removed and then afterward reapplied. It frequently tears through a friable cervix, causing at times a bothersome hemorrhage. All of these disadvantages can be avoided by using a double tenaculum such as Skene's (see Fig. 2910), or the ordinary bullet forceps will answer. With the double tenaculum two punctures only are made in the anterior lip of the cervix, instead of half a dozen. The instrument is clamped on by means of the catch, so that no hand is required to hold it. It will of itself act as a depressor to keep back the bulging anterior wall. So long as it remains fastened to the cervix, the uterus will be under perfect control. A retroverted uterus may be replaced with great ease with this instrument. This is accomplished by drawing on the cervix and making it describe a circle backward into the posterior fornix. Great care should be used in drawing down the cervix, as this is a procedure that may do much harm and cause considerable pain, if adhesions or inflammatory conditions exist. The bimanual examination should have previously disclosed any condition of immobility of the organ, or any lack of elasticity of the ligaments. Unless the uterus can be drawn down easily without force, the procedure should not be attempted.

The Probe and the Sound.—After the cervix and its surroundings have been inspected, the next procedure will be to examine the cavity of the uterus by means of the probe or the sound.

The probe is a very flexible piece of copper or silver wire, with an olive-shaped tip, and is designed to bend on meeting the slightest obstruction. It is therefore a safe instrument with which to make an exploration of the uterine cavity (see Fig. 2911).

The sound is of a larger diameter, and is much stiffer than the probe, but is capable of being bent into any shape that may be required. Simpson's sound is the instrument usually employed (see Fig. 2912). It has a bulbous tip and at a point two and a half inches from the end there is an enlargement which denotes the normal length of the uterine canal. The shaft is marked in inches for purposes of measurement.

The sound is an instrument capable of inflicting much damage, and requires great care in its use. Great harm may be done by employing it recklessly and unskilfully. The novice had better by far use the probe only for his investigations until he has acquired a sufficient knowledge of the technique, and some skill in his manipulations.

The probe will reveal nearly as much as the sound, and there is no especial advantage, in the majority of instances, in employing the more dangerous instrument.

The first precaution to be taken before invading the uterine cavity with any instrument is to ascertain the date of the last menstruation. If this precaution is omitted the physician will frequently find that he has unintentionally interrupted a commencing pregnancy, sometimes to the delight of his patient, who may have such an object in view in requesting an examination for other trouble. The technique of using the sound is practically the same as that for introducing the probe.

Fig. 2910.—Skene's Tenaculum, with Catch.

The instrument should never be introduced without having the cervix clearly in view, so that it may be passed directly into the canal of the cervix without coming in contact with the surrounding parts. The method of introducing the instrument by sense of touch should be condemned just as strongly as the old method of catheterizing a patient, when it was considered desirable for the physician to be able to introduce a catheter into the bladder under a sheet.

Fig. 2911.—Uterine Probe.

The cervix should first be painted with tincture of iodine and the instrument that is to enter the uterus should be sterilized as if for an operation. Boiling is the safest plan, but when the conveniences are not at hand, the instrument can be immersed in ninety-five per-cent. carbolic acid for a few moments, and then in alcohol to neutralize the acid. The bimanual examination will have given the physician a fairly accurate idea as to the shape of the uterus, and he should shape his probe or sound accordingly. The instrument is to be held lightly between the thumb and forefinger and the cervix steadied by the tenaculum. The tip is then passed into the external os and allowed to find its way along the canal. It will frequently become obstructed at the internal os by a shoulder or pocket in the mucous membrane, in which case a gentle twisting motion or withdrawal will enable the sound to pass the obstacle. The probe will pass a constriction at the internal os, while the sound may be arrested. Sometimes, in anteflexion, the constriction may be spasmodic in character; if such is the case, the stricture will relax if the sound is held firmly against it for a few moments. When the instrument reaches the fundus, the forefinger is slid along the shaft until it comes in contact with the cervix. The probe or sound is then withdrawn and the depth of the uterine canal can readily be noted.

The sound should not be used to determine the mobility of the uterus. It is such a powerful lever that the uterine mucosa will be unnecessarily injured even if worse damage is not done. The degree of mobility of the uterus can be determined better and more safely by the bimanual examination. In the healthy uterus the sound, if skilfully passed, should not cause either pain or hemorrhage. The occurrence of one or both of these symptoms denotes a diseased condition of the endometrium. The patency of the external and internal os, irregularities on the uterine mucosa, and the presence of growths in the canal are ascertained by means of the sound. The sense of touch, as communicated through the sound, is here brought into play, and this necessitates that the instrument must be held very lightly between the thumb and fingers in order to appreciate any delicate variation.

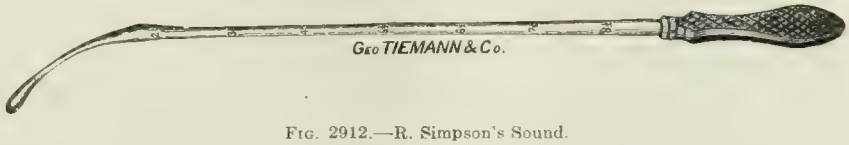

Fig. 2912.—R. Simpson's Sound.

The use of the sound as a repositor is to be condemned. Any evidence of acute inflammation of the uterus or its appendages prohibits any intrauterine manipulations.

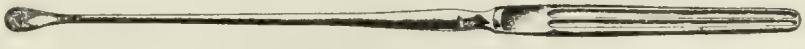

Fig. 2913.—Skene's Curette.

The Curette.—The curette is a valuable instrument for diagnostic purposes. The curette for this purpose should be small, so as to pass the internal os without difficulty. It should be dull and very flexible, so that no damage can be done with it. The spoon-shaped curette, as shown in Fig. 2913, is especially adapted

for diagnosis, although a dull wire curette may be used. The spoon curette enables one to scrape off shreds of tissue and epithelium from the endometrium, which should be examined under water to disclose their gross appearance, while they are to be submitted to microscopic examination for more accurate diagnosis. All that has been said in regard to employing the sound applies equally to the curette. The instrument must be properly sterilized and given the shape of the canal which has been accurately ascertained by means of the sound or probe. It is to be used with all gentleness. The curette is not to be used in the office to curette the uterus as for an operation it should serve simply as a means of procuring a small amount of tissue or débris from the uterine canal for diagnosis only.

Dilatation of the Cervix.—This is a procedure which is sometimes necessary in order to admit the passage of the examiner's finger into the uterine canal for purposes of diagnosis. As it is of such a nature as to require an anesthetic for its proper performance, as well as the usual preparations for a surgical operation, its description does not belong in this article.

Examination of the Urethra and Bladder.—See the articles on *Urethra, Female,* and *Bladder, Diseases of the.*

The Microscope.—The aid of the microscope for differential diagnosis is of especial value in gynecological examinations. The recognition of the gonococcus by the microscope is of prime importance in investigating the character of vaginal or other discharges. In fact it is impossible to be sure of the character of a discharge without its aid. As the important position that the gonococcus holds as an etiological factor in diseases of women becomes better known, the necessity for the use of the microscope by the gynecologist appears in a clearer light. Commencing epithelioma and carcinoma are to be detected with positiveness only by submitting uterine scrapings or small pieces of cervical tissue to microscopical examination, and they may be removed with ease during the examination under local anesthesia with the patient in the Sims posture. GEORGE GRAY WARD, JR.

Hæmadipsa.—A genus of land leeches. These animals live under leaves or rubbish in oriental countries and rush forth when their prey approaches. They bite gently but usually make a deep wound, the scar of which often takes months to disappear. They fill themselves in about thirty minutes, and then drop off. See *Hirudinea.* A. S. P.

Hæmadipsinæ.—A family of gnathobdellid leeches which live on land. The principal genus is *Hæmadipsa.* See *Hirudinea.* A. S. P.

Hæmamœba.—A synonym for the genus *Leucocytozoon,* trypanosome-like flagellates parasitic in birds. Also a synonym for *Plasmodium,* a genus of protozoans that causes fevers in man and other warm-blooded animals. See *Protozoa.* A. S. P.

Hæmaphysalis.—A genus of ticks which contains *H. leachi,* the South African dog tick. This arachnid spreads *Babesia canis,* the cause of bilary fever in dogs. See *Protozoa.* A. S. P.

Hæmatobia.—A genus of biting flies allied to tsetse-flies. Two species are known in Europe and one in Java. See *Insects, Parasitic.* A. S. P.

Hæmatococcus.—A synonym for the genus *Babesia* flagellate protozoans. These are *Herpetomonidæ* which live as parasites. *B. bigemina* is the cause of Texas fever in cattle. See *Protozoa.* A. S. P.

Hæmatopinus.—A genus of lice. Two species occur on man and several on monkeys, dogs, horses and other animals. Some carry protozoan diseases. See *Insects, Parasitic.* A. S. P.

Hæmatopota.—A genus of flies, *Tabanidæ,* many species of which are blood suckers. See *Insects, Parasitic.* A. S. P.

Hæmentaria.—A genus of leeches. The bite of *H. officinalis,* found in Mexico, is said to cause drowsiness, buzzing in the ears, and a painful rash. See *Hirudinea.* A. S. P.

Hæmoflagellata.—A group of somewhat diverse flagellate protozoans which usually appear alternately in the blood of a vertebrate and the digestive tract of a blood-sucking invertebrate host. *Trypanosoma, Trypanoplasma, Crithridia, Leptomonas, Leishmania,* and *Prowazekia* are the most important genera. See *Protozoa.* A. S. P.

Hæmogregarinidia.—An order of Telosporida in which either the gametocytes or the schizonts, or both, are present in red or white cells in the peripheral blood of vertebrates, and in which schizogony takes place either in the cells of the peripheral blood, or in those of some other organ, while sporogony occurs in the body of some blood-sucking invertebrate, such as a leech, a tick, a mite, or an insect. This order contains a single genus, *Hæmogregarina,* which includes many species occurring in fishes, amphibians, reptiles and mammals. See *Protozoa.* A. S. PEARSE.

Hæmoproteidæ.—A family of parasitic Mastigophora which contains a single genus, *Hæmoproteus,* with several species parasitic in birds and reptiles. See *Protozoa.* A. S. P.

Hæmoprotozoa.—*Binucleata.* An old term used by Sambon to include certain parasitic flagellates. See *Protozoa.* A. S. P.

Hæmosporida.—An order including protozoans that are parasites in blood corpuscles, red or white, of vertebrates where schizogony takes place. Sporogony occurs in the digestive tract of an invertebrate. Important representatives are *Hæmabœa, Halteridium, Leucocytozoon, Hæmogregarines* and *Piroplasma.* See *Protozoa.* A. S. P.

Hagedorn, Werner.—Born at Westhausen, Germany, July 2, 1831. He studied medicine in Berlin under Johannes Mueller and B. von Langenbeck, and received his doctor's degree in 1854, the title of his graduating thesis being: "De forcipe Schoelleriana obstetrica." He was for many years the Director of the Surgical Department of the Magdeburg Hospital, and was honored with the title of "Geheimer Sanitätsrath." He died at Magdeburg June 20, 1894.

Hagedorn contributed a number of brief treatises to von Langenbeck's Archiv and to the Verhandlungen der Deutschen Gesellschaft für Chirurgie. To American surgeons he is best known as the inventor of "Hagedorn's needle." A. H. B.

Hahnemann, Samuel Christian Friedrich.—Born at Meissen, Saxony, April 10, 1755. He re-

ceived the degree of Doctor of Medicine from the University of Erlangen in 1779. After practising his profession in various places he finally, in 1789, settled in Leipzig. In 1790 he translated W. Cullen's "Materia Medica" into German, and he was struck, during the progress of this work, with the fact "that the symptoms produced by quinine on the healthy body were similar to those of the disordered states it was used to cure. He had previously felt dissatisfied with the state of the science of medicine, and this observation led him to assert the truth of the 'law of similars,' *similia similibus curantur* or *curentur* —*i.e.* diseases are cured (or should be treated) by those drugs which produce symptoms similar to

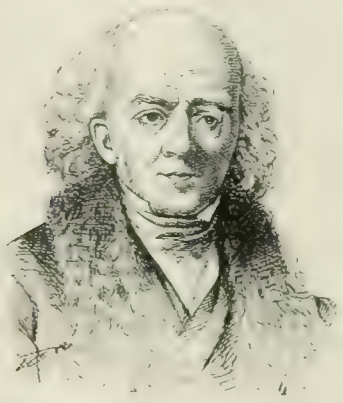

Fig. 2914.—Samuel Christian Friedrich Hahnemann.

them in the healthy. He promulgated his new principle in a paper published in 1796 in C. W. Hufeland's *Journal*, and four years later, convinced that drugs in much smaller doses than were generally employed effectually exerted their curative powers, he advanced his doctrine of their potentization or dynamization. In 1810 he published his chief work, 'Organon der rationellen Heilkunde, containing an exposition of his system, which he called homeopathy; and in the following years appeared the six volumes of his 'Reine Arzneimittellehre,' which detailed the symptoms produced by 'proving' a large number of drugs,—*i.e.* by systematically administering them to healthy subjects." (Encyclopædia Britannica.) In 1821 he was forced, by the hostility which his new doctrines had provoked among various established interests, particularly those of the apothecaries, to leave Leipzig. Upon the invitation of the Grand Duke of Anhalt-Coethen, he went to live at Coethen; and, after remaining there fourteen years, he removed to Paris, where he practised with great succes until his death on July 2, 1843.

For further information consult Albrecht (Hahnemann's Leben und Werken, Leipzig, 1875) and Bradford (Hahnemann's Life and Letters, Philadelphia, 1895). A. H. B.

Hair, Anatomy of.—See *Skin and its Appendages.*

Hales, Stephen.—An English clergyman, born at Bekesbourne, England, September 7, 1677. He received the degree of Master of Arts from Cambridge University in 1703, and that of Bachelor of Divinity in 1711. After taking Holy Orders he studied anatomy and chemistry with his friend, William Stukely, an English antiquary who practised medicine for a short time. In 1717 he was elected Fellow of the Royal Society, which awarded him the Copley medal in 1739. On the death of Sir Hans Sloane, in 1753, Hales was chosen foreign associate of the French Academy of Sciences. He died at Teddington, January 4, 1761.

The fame of Hales as an experimental physiologist rests largely upon the fact that he was the first to measure the blood pressure and devised the first manometer, after which that of Poiseuille appears to have been patterned. The accounts of his experiments are given in his two volumes of "Statical Essays." The first of these "Vegetable Statics," published in 1727, contains a description of the method employed by him to determine the force of the movement of sap in vegetable stems and pictures of the curved mercurial gauge devised for use on a piezometer. The second volume, "Hemostatics, or an Account of some Hydraulic and Hydrostatical Experiments made on the Blood and Blood-vessels of Animals," etc., 1733, contains a description of his experiments made to determine the intraarterial blood pressure. He also attempted to estimate the number of capillary vessels in the body by means of calculations based upon the relative diameters of the aorta and a capillary and the amount of blood expelled at each ventricular systole. Later experiments have thrown doubt on the accuracy of his estimate, but that the calculation was made at all shows the scientific curiosity that occupied his mind in the intervals of his clerical labors. He is also credited with the invention of a forceps for the extraction of vesical calculi. T. L. S.

Hall, Marshall.—Born at Basford, England, Feb. 18, 1790. He studied medicine at the University of Edinburgh, and received his doctor's degree from that institution in 1912. During the following two years he served as Resident House Physician at the Royal Infirmary, Edinburgh. In 1814 he visited the medical schools of Paris, Berlin, and Goettingen. In 1817 he settled in Nottingham as a general practitioner, and in 1825 he was chosen Physician to the Nottingham General Hospital.

Fig. 2915.—Marshall Hall.

In 1826 he removed to London, and between that date and the year 1837 he published a number of important treatises on medical topics. His "ready method" for resuscitation in drowning and other forms of suspended respiration—generally known in this country as Marshall Hall's method of artificial respiration—has been the means of saving innumerable lives. He died at Brighton, August 11, 1857.

Of Marshall Hall's published writings the following deserve to receive special mention: "Observations on Blood-Letting, founded on Researches on the Morbid and Curative Effects of Loss of Blood," 1830; "Experimental Essay on the Circulation of the Blood in the Capillary Vessels," 1831; "On the Reflex Function of the Medulla Oblongata and the Medulla Spinalis," 1832; and "On the True Spinal Marrow, and the Excito-motor System of Nerves," 1837. A. H. B.

von Haller, Albrecht.—Born in Berne, Switzerland, October 16, 1708. In 1723 he visited the University of Tübingen for the purpose of studying medicine, and he there received his first instruction in anatomy and general medicine from Camerarius and George Duvernois, who were among the celebrated teachers of that day. About this time he went off on a pleasure party with some of his fellow students and they all became intoxicated. This occurrence made such a deep impression on his mind that he vowed he would never again touch wine; and he kept this vow during the remainder of his life. In 1725 he visited the University of Leyden, in Holland. Boerhaave, who gave instruction in medicine and botany, and Albinus, who had already, notwithstanding his youth, begun to teach anatomy by direct demonstrations, extended a most friendly welcome to Haller. His strong leaning toward the study of anatomy and his eagerness for work were more particularly stimulated, however, by the splendid anatomical collection of Ruysch* and by the sight of this anatomist himself (aged ninety years) still hard at work on his anatomical specimens. When he was only eighteen years old, he received the degree of Doctor of Medicine, from this University, and during the next few months visited England and France, making the personal acquaintance of such men as Hans Sloane, Douglas, and Cheselden in England, and Geoffroy, Le Dran, and Winslow in Paris. Upon his return to Berne, in 1729, he began the practice of medicine. In 1734 the Republic of Berne built a large amphitheatre suitable for anatomical demonstrations and appointed Haller Professor of Anatomy. In 1735 he also received the appointment of chief of the Public Library. In 1736 he was called to the University of Goettingen, to fill the Chair of Anatomy, Botany, and Surgery. In 1742 he published two large volumes filled with beautiful plates of Swiss botanical specimens.

In 1747 he published his "Primæ lineæ physiologiæ," and then, ten years later, his great work on Physiology—the work which was to make his name immortal. He also wrote poetry of no mean order of merit. He died on July 22, 1755.

The variety of Haller's natural gifts and the remarkable excellence of his completed works are still a source of wonder to all who read the history of his life. A mere list of his published works would fill several pages of this HANDBOOK. The following, however, deserve to receive special mention, as they possess very great merit. Their titles are as follows: "Hermanni Boerhaave, prælectiones Academicæ in proprias institutiones rei medicæ" (vol. i., Goettingen, 1739; vol. ii., 1740; vol. iii., 1741; vol. iv., 1743; vols. v. and vi., 1744); "Elementa Physiologiæ corporis humani," 8 vols., 1757–1766; "Bibliotheca anatomica," 2 vols., 1774–1777; "Bibliotheca chirurgica, qua scripta ad artem chirurgicam facientia a rerum initiis recensentur," 2 vols., 1774–1775, and "Bibliotheca medicinæ practicæ, qua scripta ad partem medicinæ practicæ facientia a rerum initiis ad annum 1775 recensentur," vols. iv., 1776–1788.

A. H. B.

Hamamelis.—WITCHHAZEL. This plant, *Hamamelis virginiana* Linne (Fam. *Hamamelidaceæ*), yields two official drugs, namely HAMAMELIDIS FOLIA, the dried leaves, collected in autumn, and H. CORTEX, the dried bark and twigs. The witchhazel plant, also called Snapping hazel, Spotted alder and Winter bloom, is a tall, slender, straggling shrub growing commonly, in moist woods, over a large part of the United States. Its flowers are small, in little, sessile, axillary clusters, and appear late in the autumn. They persist through most of the winter, the fruit from them ripening in the following summer. Calyx four-parted; corolla of four long, narrow, strap shaped, yellow petals; stamens, eight, short; pistil, one with two styles; and a two-celled, two-ovuled ovary.

The leaves are stoutly and very shortly petioled, the blade seven to fifteen centimeters (3 to 6 in.) long and nearly as broad or occasionally even broader, highly inequilateral, oval, with a very oblique, slightly cordate base, and usually a very short obtusish point at the summit, the margin coarsely sinuate; thickish, dull green and with obscure venation above, paler or brownish-green, with a satiny luster and very prominent principal veins underneath, nearly smooth, the few hairs of the lower surface having much thickened walls and a very small lumen; odor rather faint, characteristic; taste astringent, slightly aromatic, bitter.

The definition of the bark is faulty in that it does not restrict the size of the twigs and thereby the amount of inert wood. The bark occurs in irregularly quilled or bent pieces, one to two millimeters thick; outer surface grayish-brown, with numerous lenticels, or reddish-brown, with short transverse ridges or scars, or somewhat scaly in older bark; the thin, corky layer easily removed from the pale cinnamon-colored middle bark; inner surface pale cinnamon-colored, or sometimes yellowish, smooth, or finely striate; fracture of young bark short, of old bark tough in the bast layer; odor faint; taste astringent, somewhat bitter and pungent. Twigs flexible and tough, of irregular length, not more than six millimeters in diameter, branching, or bearing nodes at intervals of two to five centimeters; externally varying from yellowish-brown to deep purplish-brown, lightly longitudinally wrinkled, and having scattered small circular whitish or pale lenticels; bark occupying about one-fifth of the radius; wood greenish-white, lightly radiate, and exhibiting one to three annual rings; pith centric, small.

A number of analyses of this drug have been made without discovering anything to explain its reputed virtues. It is not poisonous in any quantity. There is some *tannin*, and a small amount of *essential oil*.

FIG. 2916.—Witchhazel; Flowering Branch. (Baillon.)

It is an old remedy of the Indians, and is said to have been introduced to our notice by them; but its present popularity as a wash for bruises and wounds in household-practice is of very modern growth.

For twenty years or so it has been, in this country, the most widely used domestic vulnerary, taking the place in the popular estimation of arnica, which had held sway for a generation before. It is usually employed in the form of a distillate, made by distilling a very weak mixture of alcohol and water (six-per-cent. alcohol). It has an odor and faint taste derived from the drug, but not enough oil or extract to be estimated

* This was his second collection; the first one having been sold to the Czar of Russia for 30,000 florins.

in any other way. The odor is pleasant and suggestive of liniment, and the preparation is on the whole a fair evaporating lotion. A fluid extract (*Extractum Hamamelidis Fluidum*) is official, and contains, besides the fragrant principles, considerable tannin, which the

Fig. 2917. -Witchhazel; Flowers. (Baillon.)

distilled preparation of course does not. It may be diluted for washes, vaginal douches, etc. Witchhazel at present is rarely given internally.

The bark is similarly employed, and much of the distillate is said to be prepared from it. It is regarded by many as being superior to the leaves.

Henry H. Rusby.

Hamartoma.—From the true tumors (blastomas) there must be carefully separated the tumor-like malformations or disturbances of development that show no autonomous excess of growth. Such errors of development may be divided into five classes: (1) Defects in tissue-combination (*hamartia*); (2) Separation or misplacement of anlage (*chorista*); (3) Non-use or non-development of anlage that later develop; (4) Abnormal persistence of embryonic tissue and organs; (5) The pathologic filling-up or obliteration of embryonic clefts. The hyperplasia of the tissues resulting from such disturbances of development may give rise to formations that externally resemble neoplasms. These are classed by Albrecht and Borst as *hamartoma* and *choristoma*. Should these growths form the basis for true autonomous neoplastic growth the resulting tumors can be classed as *hamartoblastoma* and *choristoblastoma* respectively. Nearly every variety of neoplasm has corresponding *hamartomas* or *choristomas* from which it must be differentiated, and such a differential diagnosis is sometimes very difficult. The broadest pathological experience is here needed; probably in no other field of practical diagnostic pathology are so many errors of diagnosis made as in the differential diagnosis of the hamartomas and choristomas from the true blastomas. Among the most common *hamartomas* are the so-called fibroma of the medullary pyramids of the kidney, certain fibroadenomas of the breast, neurofibroma, myxoma of nerve-trunks, various forms of heterotopous lipoma, chondroma, and osteoma, the hemangiomatous and lymphangiomatous nævi, elephantiasis, macroglossia, various adenomyomas, cirsoid neuroma, pseudoneuroma, various forms of neuroglioma ganglionare and gliomatoses, papillomas of the skin, intestinal polyps, and various adenomas of liver, kidney, and mamma. Examples of choristoma are misplaced adrenal tissue in testis, ovary, liver, pancreas, or elsewhere, dermoid, epidermoid, entodermal, and mesodermal cysts, various forms of chondroma, osteoma, lipoma, myxoma, and fibroma. A. S. Warthin.

Hamilton, Frank Hastings.—Born in Wilmington, Vermont, September 10, 1813. He received the degree of M. D. from the University of Pennsylvania in 1835. After practising for a few years in Auburn, N. Y., he removed, in 1844, to Buffalo. In 1847 he was associated with Drs. James P. White and Austin Flint in organizing the Buffalo Medical College. In 1862 he settled in New York City, and for a number of years (up to 1875) he held the Chair of Surgery in the Bellevue Hospital Medical College. His death occurred in that city on August 11, 1886.

Dr. Hamilton made several important contributions to medical literature. Those which deserve special mention are the following: "Fractures and Dislocations"; a "Treatise on Military Surgery"; and a "General Treatise on Surgery." A. H. B.

Hamularia.—A subgenus of the round-worm genus Filaria. *H. equi* is common in horses and asses; it has been found in human beings several times. See *Nematoda*. A. S. P.

Hand.—Cresollius calls the hand "the minister of reason and wisdom." As the active servant of the brain, adjusted for the most delicate and varied uses, it has always been held in peculiar honor. The coat-of-arms of the surgeons' guild of the Middle Ages was a hand, with outspread fingers and an eye in their midst, typifying thus the noble art of chirurgie, which name was itself derived from χείρ, the hand, and ἔργον, work. Respect for this important member has even been carried so far that it has been supposed to contain a force within itself capable not only of intelligent action, but of transmission beyond the body. When we regard the high degree of muscular coördination which it possesses we readily see whence originates the first of these popular fancies, for the hand of the skilled musician, artist, or handicraftsman is a very different organ from that of the untrained and inexpert novice. The very word "handy" expresses this idea.

As to the second notion, it appears to be founded upon the extraordinary degree of tactile sensibility which the hand possesses. The laying on of hands has been a favorite method of healing from the very earliest historical period, and is still prevalent, not only where the royal touch is believed to be a sovereign remedy for "king's evil," but also among the so-called healing mediums.

The mesmeric passes were believed to be efficacious only when performed with the ends of the fingers, in order that the "force" might be drawn off into the patient's body. Von Reichenbach's patients saw flames of "od" force issuing from the ends of the fingers; many worthy people have no doubt that a nervous headache can be cured by some transfer of this force by means of passes over the brow of the sufferer; and we have lately had a revival of the old astrological theory of an "astral fluid" which is more transmissible from those with pointed fingers. Obscure nervous sensations felt in the fingers and along the nerve tracts are believed to be caused by this force or fluid. Owing probably to this superstitious reverence, we find that the physicians of the Middle Ages used the detached hand of a corpse for the scattering of tumors and the reduction of swellings.

The use of this strange remedy still survives. The author has recently found several authentic cases of such application. In one it was used for the cure of a white swelling, and in another for a protracted intermittent fever, a female homeopathic physician vouching for its efficacy. She explained this to the writer by stating that the "morbid processes going on in the dead hand attracted the disease and removed it" (!). Sometimes the virtue of the deceased is believed to have a marked influence. This was shown in the case of a well-known Catholic priest who died some years ago in Washington, and in that of a Carmelite nun in Baltimore. Many applications of the dead hand were made in both cases for the cure of the sick and afflicted, showing that the old belief is still active.

Another superstition which had a prominent place

in the black art of the Middle Ages was that of the "hand of glory." This was a dead right hand of a murderer prepared with appropriate conjurations, in which was placed a magic candle made of murderer's fat and the hair of the dead. This was believed to prevent sleepers from awakening and to open locks and bars. As late as 1831, such a hand was left by thieves in a house in Loughcrew, Ireland. Thieves in Mexico use for a similar purpose the left hand and arm of a woman dying in her first childbed, and in 1875 a Mobile negro carried around with him the hand of his murdered victim to insure himself against detection.

Sir Charles Bell, the author of the celebrated "Bridgewater Treatise on the Hand,"[1] says: "We ought to define the hand as belonging exclusively to man, corresponding in sensibility and motion with that intelligence which converts the being who is weakest in natural defence, to a ruler over animate and inanimate nature." However flattering to our pride this statement of the great physiologist may be,

	Hand.	Foot.		Hand.	Foot.
Man	11.82	16.96	Chimpanzee	18.00	21.00
Gorilla	14.54	20.69	Orang	20.83	25.00

This superior length is due mainly to the metacarpal bones and phalanges.

With regard to the primitive origin of limbs two distinct views have been advanced by anatomists. According to the first the proximal part of the limb, which we are accustomed to call the shoulder or pelvic girdle (scapula and clavicle for the arm, innominate bone for the leg), arises from visceral arches of the vertebræ, and radial bars of cartilage are set upon these for the support of the fins. The pelvic girdle is thought to have become shifted backward in a marked degree. A complete homology, therefore, is believed to exist between the thoracic and the pelvic limbs.

The opposing view, which has recently been rapidly gaining ground, is that the shoulder and pelvic girdles are formed from coalesced vertebral elements. It is held that the most primitive form of limb is

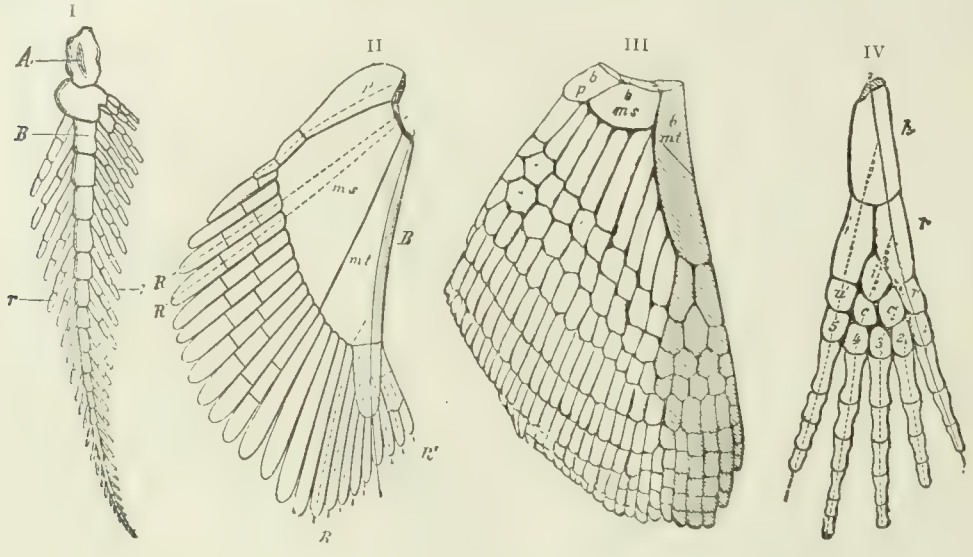

Fig. 2918.—Skeletons of the Thoracic Limb of Lower Vertebrates, showing the Gradual Development of the Hand.

modern investigation has shown that it is not anatomically correct, as there is nothing in the structure of the human hand that distinguishes it, except in degree, from that of anthropoid apes. Even Huxley's statement, that the apes do not possess an extensor of the metacarpal bone of the thumb, is open to question. Comparative anatomy shows us in fact that a general typical form for the thoracic limb and hand pervades the entire vertebrate series. This is especially marked in the mammalia, and in many cases the student of human anatomy has no difficulty in determining at once the different bones of the forefeet of an animal which he has never before seen. In one case within the author's experience, a professor of obstetrics who was not an anatomist, was obliged to examine a class in anatomy, and procured from the cabinet the skeleton of a bear's forepaw, which he passed around as belonging to the human skeleton. As the functions of the member vary, the different parts become reduced or increased either in size or in number, but a general plan pervades the whole, and the fin of a fish, the wing of a bird or a bat, the paw of an animal, are all constructed on a single type.

While the differences between the human hand and that of the higher apes are not essential, being only those of degree, yet the relative proportions of the different parts distinguish it markedly. The following table from Humphry shows the size of the hand and the foot relative to the stature taken as 100:

simply a lateral skin fold extending along the whole body, and that into this certain cartilaginous processes or rays (actinophores of Ryder, pterygophores of Parker) extend. Each of these may bear several others extending radially through the fin. When necessary for more special forms of locomotion, the actinophores become united into solid bars constituting the shoulder and pelvic girdles, and the other skeletal elements are distally situated rays. Fig. 2439 shows various forms of fins found in primitive fishes; and it will be seen that there is a certain general resemblance to a hand with a large number of digits. According to this view there is no absolute homology between the thoracic and pelvic limbs, but only a homodynamy. Between fishes with fins and amphibia with feet there is a gap which has not yet been filled up by the discovery of intermediate forms, but it appears probable that the limb in its reduced state is the result of adaptation to walking instead of swimming.

In swimming it is necessary only to propel the body forward, in walking it must be also supported and raised; hence the necessity of the strong proximal bones and the bending at the shoulder, elbow, and wrist, and at the hip, knee, and ankle.

Fig. 2918, IV., shows how closely the plan of the hand and arm of an amphibian corresponds with that of man. From this point up through mammals there are many modifications, produced by the peculiar

functions which the limbs are called upon to perform. When of use for prehension, digging, etc., the five-fingered type remains, and it is in fact the most persistent of all; but occasionally the occurrence of extra digits in the human species reminds us of a far-off ancestry, in whom the rays were more numerous. When the anterior limbs are used more for locomotion they become variously modified by stress and impact, and lose unnecessary digits. The reduction always takes place laterally. First the thumb becomes rudimentary or disappears, then the little finger, next

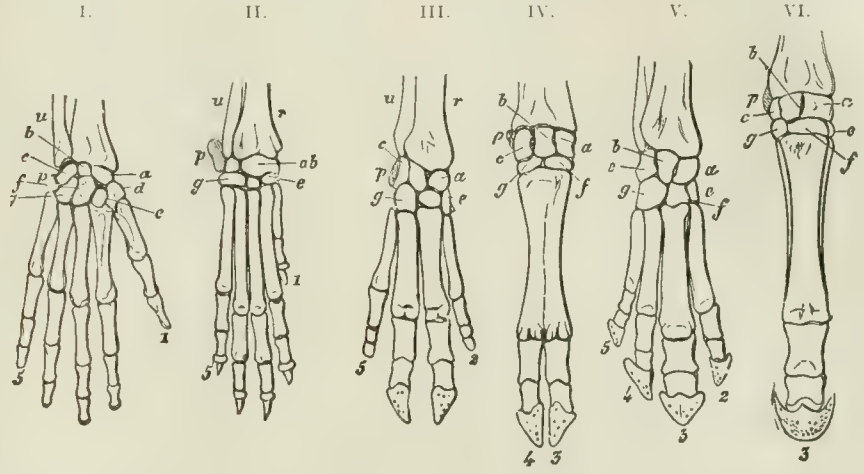

Fig. 2919.—Skeleton of Hand or Forefoot of Six Mammals. I., Man; II., dog; III., pig; IV., ox; V., tapir; VI., horse. *r*, Radius; *u*, ulna; *a*, navicular; *b*, lunate; *c*, triangular; *d*, greater multangular; *e*, lesser multangular; *f*, capitate; *g*, hamate *p*, pisiform; 1, thumb; 2, index-finger; 3, middle finger; 4, ring finger; 5, little finger. (Gegenbaur.)

the second finger, then the fourth, and soon. The discussion of the various causes for this is of extreme interest, but would exceed the proper limits of this article. The principal typical forms are shown in Fig. 2919

Embryological evidence as to the development of the hand agrees, as far as it can at present be understood, with the facts observed in the animal series.

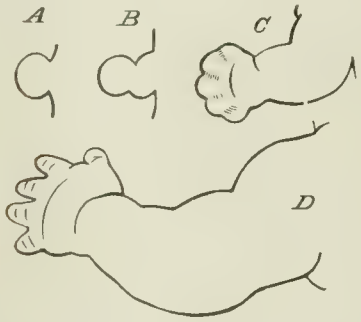

Fig. 2920.—Outlines of the Anterior Extremities of Human Embryos at Different Ages. (Allen Thompson, after His.) *A*, At four weeks; *B*, at five weeks; *C*, at seven weeks; *D*, at nine or ten weeks.

The first rudiment appears as a thickening and crescentic protuberance (see Fig. 2920, *A*), which grows laterally from the body wall. Further outgrowth may be arrested at this point, and in that case we have a child born with a hand springing directly from the shoulder, a species of monstrosity reminding one of the flipper of a seal, and hence called phocomelus. Normally, however, other segments are developed between the first bud and the body wall (Fig. 2920, *B*), and in these the bones of the arm develop. The formation of the fingers is first indicated by notches along the edge of the distal bud from which converging grooves run, indicating the future interdigital spaces (Fig. 2920, *C*). The first groove that appears is that between the thumb and the forefinger. The terminal phalanges soon become free, but the remaining portions of the fingers are united until the third month. If development is arrested here, we have the fingers remaining with a web between them, as in the amphibian paddle and in some quadrupeds. The thumbs become free first.

The varied structures of connective tissue, cartilage, bone, muscles, nerves, and vessels all develop gradually within this rudimentary bud, as they do in other parts of the body, by a differentiation of mesoblastic cells.

Some interesting problems are connected with the time and order of ossification of the various parts. The typical plan of the hand is shown in Fig. 2918, IV. In the wrist there are originally nine bones, which are arranged in two rows; those of the first are named systematically, the intermedium (between ulna and radius) ulnare, radiale, and correspond to the navicular, lunate, and triangular bones of man. There is then a centrale (sometimes two, as shown in the figure) found in many apes and rodents, represented in the second month of fetal life by a small independent cartilage; and then, in a second row, carpales 1, 2, 3, 4., and 5, each bearing a metacarpal bone. The first three of these correspond to the greater and lesser multangular and the capitate bones, the fourth and fifth uniting to form the hamate. The pisiform bone is generally held not to be an essential carpal element, but a sesamoid developed in the tendon of the extensor carpi ulnaris. A radial sesamoid occurs in some apes, and is occasionally found in man.

At birth all the carpal bones are cartilaginous. Ossification begins in the capitate (first year), then follow the hamate, triangular, lunate, navicular, lesser multangular and greater multangular in about that order, and at intervals of from nine months to a year, so that the carpus proper is complete during the eighth year. The pisiform is somewhat later, not ossifying until from the tenth to the twelfth year.

The metacarpals follow the rule of long bones and ossify much earlier, commencing in the shaft at about the ninth week of fetal life, an epiphysis remaining cartilaginous. In the metacarpal bone of the thumb this epiphysis is at the proximal end, but in the others it is distal. The epiphysis begins to ossify about the third year. The phalanges ossify in a similar manner, but the epiphyses in them are always at the proximal end. The agreement in ossification between the

first metacarpal and the phalanges has given rise to much speculation. It has been supposed to indicate that the missing bone of the thumb is not a phalanx, but a true metacarpal. Sappey[2] believes the metacarpal epiphysis to be the metacarpal proper, the remaining part being a phalanx, which would make the thumb agree with the other digits as to the number of segments, as is the case with some other mammals, the sloth, for example. The metacarpal bone proper has, he supposes, atrophied so as to allow the thumb to be set farther back and obtain more perfect opposability. It appears doubtful whether we ought to accept this interpretation, as a proximal epiphysis occasionally appears in the second metacarpal, and some animals have both proximal and distal. It is suggested that too much weight should not be given by osteologists to epiphyseal ossifications, as it appears probable that their presence or absence depends very much upon the activities of the animal in producing strains upon the skeletal elements.

The hand is regarded as divided topographically into three regions: the wrist, middle hand, and fingers —corresponding to the skeletal divisions of carpus, metacarpus, and phalanges.

Region of the Wrist.—Externally this region is not very precisely defined. Its upper limits are generally regarded as marked in front by the upper transverse crease which runs across the forearm, always quite well marked even in extreme extension. Its lower limits are marked by another furrow, which curves around the base of the thumb. Behind, the marks of limitation are by no means as clear. Upon strongly extending the hand (dorsal flexion) there appear three or more furrows which correspond in a general way to the joints of the wrist, viz., the radiocarpal, mediocarpal, and carpometacarpal. Although described as such by Malgaigne, they are not practically good guides to the joints in question.

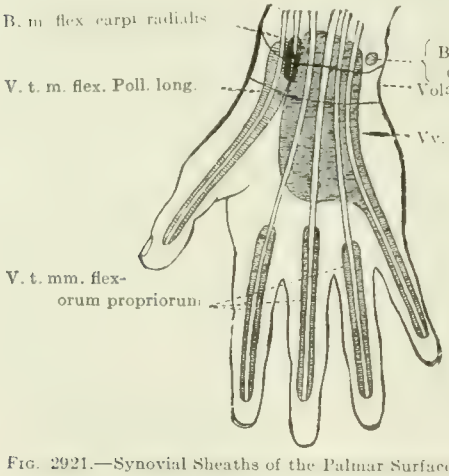
B. m. flex. carpi radialis
V. t. m. flex. Poll. long.
V. t. mm. flexorum propriorum
B subtend. flex carpi ulnaris.
Volar carpal ligt
Vv. t. digitales

Fig. 2921.—Synovial Sheaths of the Palmar Surface of the Hand

The muscles of the arm as they reach the wrist all become reduced to comparatively small tendons, which pass over this region to a distal insertion, the flexors lying on the volar surface, and the extensors on the dorsal and radial. The wrist is, therefore, the narrowest part of the limb, and this affords an increased facility of motion to the hand as a whole. The bony parts are so arranged as to form an arch with the concavity forward, filled with the descending flexor tendons and the great vessels and nerves. Under the skin of the volar surface, which is smooth and without hairs, can easily be felt the prominent points of this arch, viz., on the radial side the tubercle of the navicular, on the ulnar the pisiform. These vary in prominence in different individuals. It is not uncommon for uninstructed persons to suppose that they have "a bone out," and unscrupulous quacks take advantage of this notion to work supposed cures.

Upon flexing the hand a tendon starts up. This belongs to the palmaris longus, and in a lean wrist it can be plainly seen to spread out and become continuous with the palmar fascia. On the radial side of the palmaris tendon, and close to it, can be easily felt the tendon of the flexor carpi radialis. Behind and between these two lies the median nerve. When the

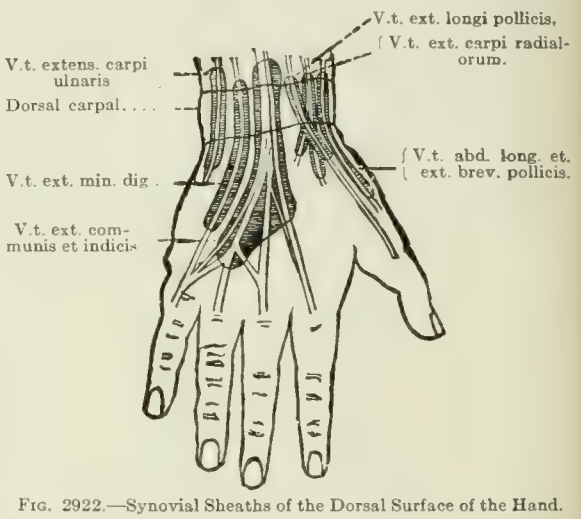
V.t. ext. longi pollicis,
V.t. ext. carpi radialorum.
V.t. extens. carpi ulnaris
Dorsal carpal. . . .
V.t. ext. min. dig .
V.t. ext. communis et indicis
V.t. abd. long. et.
ext. brev. pollicis.

Fig. 2922.—Synovial Sheaths of the Dorsal Surface of the Hand.

superficial volar artery is large, it may be seen to pulsate where it lies alongside of the tubercle of the navicular. The radial artery usually does not appear here, having already passed laterally under the extensor tendons of the thumb to reach the dorsum of the hand. The point where the pulse is usually felt is not, strictly speaking, within the anatomical region of the wrist, but upon the lower end of the radius. It is admirably adapted for the purpose, as the artery here lies upon a bony bed, may be easily compressed, and is about to make a sudden and abrupt curve. Hence a careful palpation shows at once the amount of tension of the arterial wall. By extending the wrist, the artery may be slightly stretched and the structures above it rendered tense, so that it may be still more easily felt. Occasionally the superficial volar is given off higher than usual, and makes a secondary pulsation, the "*pulsus duplex*" of old authors (not the pulsus dicrotus). I this case it is easy to control it by pressing it againstnhe navicular. On the ulnar side, the flexor carpi ulnaris tendon shows prominently in flexion of the wrist, as it passes down to its insertion on the pisiform bone, and radially from this the pulsation of the ulnar artery may be felt. The tendons of the flexors of the fingers lie deeper.

The skin upon the volar surface of the wrist is firmly bound to the deeper structures by a very thin layer of subcutaneous tissue, and it is therefore difficult to make a flap from it in amputating the forearm. Flexion has produced a number of transverse markings. These are the *rasceta* of the chiromants, a word derived from the Arabic, signifying wrist. There are usually three of these, and they are not only prominent in all states of the hand, but are found in fetal life. An attempt has therefore been made to give them significance as characteristic signs, but when we reflect that the hand of the fetus is also movable and actively used, and that its condition is one of pronounced flexion of all the joints, it is not surprising, in view of the peculiar relations of the skin and subdermal tissue, that these as well as the lines of the palm should be formed.

Across the volar surface of the wrist passes a thick

band of fascia, called the volar carpal ligament. This being attached to the bony prominences on either side, confines the tendons in the deep carpal furrow or canal. The continual friction of the tendons along this furrow has caused extensive synovial sacs or sheaths to be formed. Occasionally but a single one occurs, enclosing all the tendons. The usual arrangement is, however, for two sheaths (Fig. 2921), one (*vagina tendinum musculorum flexorum communium*) surrounding the tendons of both superficial and deep flexors, the other (*vagina tendinis musculi flexoris pollicis longi*) surrounding the tendon of the flexor longus pollicis. The former sheath is almost always continuous with the sheath of the little finger, and amputation of that digit is therefore more apt to be followed by extensive suppuration than that of the index, middle, or ring fingers. These extensive synovial sacs are very troublesome when inflamed, as they may lead to extensive suppuration of the forearm, and, indeed, death has been known to follow. An amputation of the hand is much less serious.

Upon the dorsal surface of the wrist the skin is much more movable, somewhat hairy, and without prominent furrows. Under it may be seen two prominent, bony eminences—first, the round head of the ulna, second, the more obscure, pointed styloid process of the radius. From this latter, running toward the thumb, the tendon of the long abductor of the thumb appears on extension, and a short distance from it the short extensor. The triangular space between these has been called *la tabatière anatomique*, or anatomist's snuff-box, because it was formerly the custom, when snuff-taking was fashionable, to carry snuff to the nose in this little hollow (Hyrtl). By pressing firmly on this space, the beating of the radial artery may be felt as it passes under the tendons to reach the first metacarpal interspace, where it passes into the palm. It here rests on the navicular and greater multangular bones. Over the back of the wrist and hand the tendons which come down from above, and are at first closely pressed together, begin to spread out to go to their respective insertions. These tendons are, from within outward, those of the extensor carpi ulnaris, extensor digiti quinti proprius, extensor digitorum communis, extensor indicis proprius, and the extensors of the thumb. These tendons are confined by a dorsal carpal ligament, and are furnished with synovial sheaths, as shown in Fig. 2922. The affection popularly known as weeping sinew (ganglion) is rather common in connection with these sheaths.

The small bones of the skeleton of the wrist are undoubtedly of considerable value in breaking and dispersing the shocks transmitted from the lower hand. The general plan of its construction has been already alluded to. We may consider the radius as bearing, first, the navicular (radiale), which in turn bears the greater and lesser multangular (carpales I. and II.), the supporters of the first and second metacarpals; second, the lunate (intermedium), which bears the capitate (carpale III.) and the third metacarpal. The ulna does not directly join with the wrist, its carpal bone, the triangular (ulnare), being separated from it by the articular disc. This bears the hamate (carpales IV. and V. united) and the fourth and fifth metacarpals. The joints and ligaments of the wrist will be treated in a separate article.

Region of the Middle Hand.—The muscles which belong to the hand proper are arranged in two groups, one upon the radial side, making an elevation called the thenar eminence; another on the ulnar side, called by correspondence the hypothenar eminence. The upper part, where these two join, is called the ball of the hand, or by French anatomists *le talon de la main*. The central portion between the eminences is the hollow of the hand, and it can be contracted and deepened by the action of the muscles on either side. Because of this, it was called by the old anatomists *poculum Diogenis*, or Diogenes' cup, in allu ion to the story that the cynic philosopher, on seeing a shepherd drink from his hand, vowed to use this, henceforth as the simplest possible utensil, instead of the rude wooden cup which he had heretofore deemed the acme of simplicity. Around this hollow are set the so-called "mounts" of chiromancy, governed, as is asserted, by the seven planets. The thenar eminence is styled the mount of Venus, and we may see a survival of the old notion in the fact that among the vulgar a titillation of this surface s believed to excite amatory passion.* It is possible that there may be an anatomical basis for this belief. An inspection of Fig. 2930 will show that the region in question lies in the boundary between the distribution of the ulnar and the median nerves, and is somewhat less fully supplied than are other parts of the hand. It is, therefore, like other regions with the same character of nerve distribution, susceptible to that obscure form of nervous excitement called "tickling," which is known to cause a variety of reflex acts. We are as yet hardly sufficiently versed in the laws of transmission of impulses to decide absolutely that this may not have a reflex effect connected with the genital apparatus, especially if aided by an association of ideas.

The lower part of the hypothenar eminence is called by palmisters the mount of the Moon, its upper the mount of Mars. At the root of the four fingers are the other mounts, which anatomical peculiarities are caused by the insertion into the roots of the fingers of the strong palmar fascia, by slips between which the tissues bulge. The mount of Jupiter belongs to the index, Saturn to the mediums, the Sun to the ring finger, and Mercury to the little finger. That this absurd farrago is not entirely obsolete the author has had ample evidence, as several intelligent people have assured him that they believe that these eminences have power to attract the seven different qualities of "astral fluid," and the doctrine has been fully set forth in more than one serious treatise within the last ten years.[3,4,5,6,7,8] Indeed, it would seem as if the advances of science in the present century, instead of extinguishing ignorant pretension, had caused pseudo-sciences to spring up by the score. Dazzled and bewildered by the evidences seen on every hand of the power of science, those untrained in the exact methods of scientific research are unable to distinguish between the true and the false, and a vast field is left open for charlatans and visionaries. The old astrologists believed not only that the hand was governed by the influence of the stars, but that certain signs were fixed upon it before birth, and became a basis from which to interpret the individual's character and constitution. Since this character and constitution have their limitations, signs for these also were found in the hand; and they further assumed that future events, such as sickness, death, and other matters of fortune or misfortune, could be foretold. There were many who went much farther than this into all the excesses of charlatanry.

The hand, being the servant of the mind, is modified and changed according to the use to which it is put; hence, say the palmisters, this organ is the appropriate index of character, and the lines of the hand, caused by the nervous influences actuating different muscles, and the tension and stress exerted on the skin, must be, if truly interpreted, a most significant guide. A little reflection will show that the modern disciples of palmistry have fallen into the same error as have the physiognomists and phrenologists, in that they expect to obtain exact and detailed particulars by examining physical characters which are highly generalized, being the result of a great number of separate physiological processes and acts.

Certain general notions as to bodily constitution,

* Iago says of Desdemona: "Didst thou not see her paddle with the palm of his hand? Lechery by this hand, an index and obscure prologue to the history of lust and foul thoughts."

use, and adaptability can undoubtedly be made out upon the inspection of the hand; but there appears to be no warrant for any exact details. The principal lines are shown upon Fig. 2923.

It will be seen that they form, rudely, the letter *M*. The one running around the ball of the thumb and marking off the thenar eminence was known to the old chiromants as the linea vitalis, or line of life. Measurements along this, made by describing arcs of circles from the several mounts, were believed to represent different periods of life, and any break in the line at

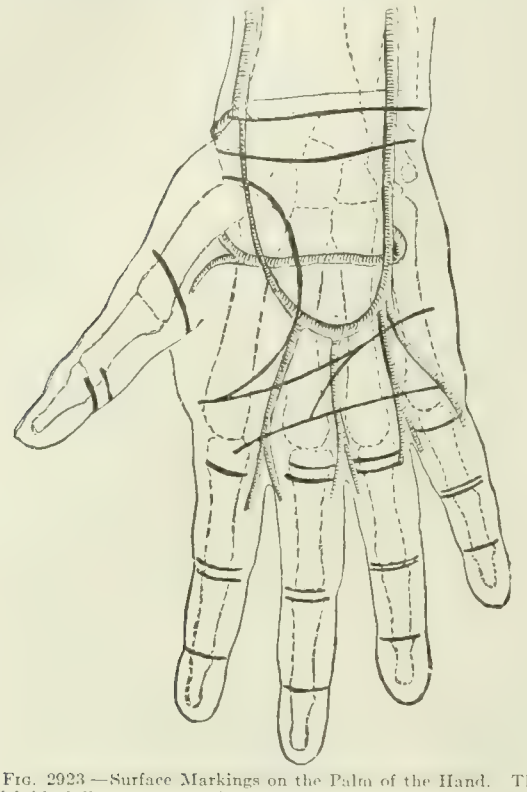

Fig. 2923.—Surface Markings on the Palm of the Hand. The thick black lines represent the chief creases on the skin. (Altered from Treves.)

the points where these crossed was said to indicate sickness or death at that period. This, gravely set forth in all recent works on palmistry, also appears in books of the sixteenth century, and probably farther back.[9] This fold, with another which occasionally occurs running from the wrist toward the finger, centrally through the palm, and called the saturnine line, or linea fortunæ, indicates to an anatomist only the action of the adductor pollicis in drawing the thumb over, and is deep or almost entirely absent as the thumb has great or little flexion. The statement is made by Langer,[10] that the saturnine line is not found in any but those of pure Caucasian race. As it is well marked in the chimpanzee, this seemed open to doubt, and the author has examined the hands of several negroes to ascertain if the statement had any foundation. In all those examined it showed with great clearness, even better than in whites.

From the radial border of the hand, near the upper end of the linea vitalis, arises the linea cephalica, or head line, which passes obliquely across the palm, disappearing near the ulnar edge. The value of this line to a surgeon is considerable, as, where it crosses the fourth metacarpal bone, it marks the superficial palmar arch (see Fig. 2923).

The arch may in some individuals be seen to pulsate strongly at this point. The commencement of the line indicates the metacarpo-phalangeal joint of the index finger. It appears to be caused by the flexion of the four fingers, and corresponds rather closely to the origin of the lumbricales from the flexor tendons.

Another line, not so extensive, is the linea mensalis, or heart line, which extends across under the mounts at the bases of the third, fourth, and fifth fingers. It is a little behind the metacarpo-phalangeal joints, and expresses flexion there of the three outer fingers, which usually act together. The name mensalis was given it because the names of the mounts were also names of months.

Besides the lines described, a number of others are mentioned by the chiromants, and in some hands there is a complete network. These might be of value for the purpose of proving personal identity in medico-legal cases. The occupation of the individual may occasion marks, callosities, and discolorations of the skin, alterations of the nails and hairs, formation of special bursæ, and even changes in the articulations, muscles, and bones, which are of importance in determining identity. The limits of this article will not permit of a full treatment of this subject, which has been very carefully examined by Vernois.[11] The shape of the hand may be permanently altered by the use of tools. The epidermis of the horny hand of a laborer may be so thick as to prevent the eruption of an abscess. The subcutaneous connective tissue of the palm is composed of short and thickly set fibrous bands, which firmly unite the skin with the deep fascia, forming partition walls of little chambers which contain fat. When the tissue is cut through, these little adipose masses, released from their confinement, extend beyond the edges of the wound. This arrangement secures a considerable degree of elasticity and protection. Abscesses do not usually point under thicker parts of the subcutaneous tissue, but seek the ball of the thumb and the hypothenar eminence.

The deep fascia is a strong and firm sheet, triangular in shape, the palmaris longus, its tensor, being inserted at the point of the triangle. Indeed, so continuously are the two united, that we may properly consider the fascia to be an expansion of the tendon. It occurs,

Fig. 2924.—Horizontal Section of the Hand through the Middle of the Thenar and Hypothenar Eminences. (Tillaux.) *a*, Metacarpal bone; *b*, first dorsal interosseus; *c*, palmaris brevis; *d*, abductor quinti digiti; *e*, flexor brevis quinti dig.; *f*, opponens quinti dig.; *g*, flexor poll. brevis; *h*, abductor poll.; *i*, opponens poll.; *j*, adductor poll.; *k*, flexor poll. long. *l*, dorsal interossei; *m*, palmar interossei; *n*, flexor sublimis; *o*, flexor profundus; *p*, superfic. volæ; *q*, median nerve, and (on medial side) ulnar artery and nerve; *r*, deep palmar arch; 1, palmar fascia; 2, lateral septum; 3, medial septum; 4, deep fascia of palm.

however, when the muscle is wanting. Opposite the fingers it splits into four processes, which are inserted by these slips at the bases of the fingers and into the sheath of the flexor tendons and the first finger-joint. Through these slips, the palmaris acts therefore as a flexor of the fingers. A chronic shortening of this sheet is known as Dupuytren's contraction, and is always accompanied by a permanent bending of

fingers. The little finger and ring finger are most affected; the thumb never, as it receives only a very insignificant slip of the palmar fascia.

A band of fascial fibers stretches across the roots of the fingers, and is known as the superficial transverse ligament. A thin fascia also separates the interosseous muscles from the rest of the palm. The metacarpal bones of all the fingers except the thumb are bound together at their distal ends by a strong strip called the transverse metacarpal ligament, and processes extend between this and the palmar fascia, making thus distinct chambers through which the flexor tendons pass as they go down to the fingers. It is through this passage that suppuration extends from the fingers into the palm.

Another series of orifices at the sides of the fingers permits the collateral vessels and nerves and the tendons of the lumbricales to reach the fingers.

The structures beneath the palmar fascia are contained in three compartments, which are separated by intermuscular septa; one (see Fig. 2924), radial, separates the muscles of the thenar eminence and becomes continuous below with the sheath of the adductor pollicis, passing with it to be inserted into the third metacarpal; the other, ulnar, is attached to the volar border of the fifth metacarpal, separating off the muscles of the hypothenar eminence. The middle compartment is the most important, as it contains, besides the flexor tendons and their accessory muscles, the vessels and nerves of the palm. The following table gives the principal facts regarding the muscles of the palm, as stated by the best authorities.

It should be noted that between the two heads of the flexor pollicis brevis the tendon of the long flexor of the thumb passes, lying in the groove of the greater multangular bone. The deep head of this muscle (supplied by the ulnar nerve), as usually described, should rather be called a portion of the adductor pollicis, with which it is somewhat closely allied. The palmaris brevis, by its contraction, probably assists to protect the ulnar artery and nerve, which pass directly under it. When the fist is firmly clenched, this muscle assists in tightening the palmar aponeurosis, and is situation is marked by a little hollow on the ulnar side of the hand. It is not usually capable of independent action, but the author has found some persons who had the power to move it at will, thus wrinkling the skin. It appears to be a muscle derived from the panniculus carnosus, like the small muscles of the face.

The lumbricales are so called because of their round, worm-like appearance. The old anatomists, because of their use in flexing and extending the fingers, called them fiducinales, or fiddler's muscles.

	Origin	Insertion	Innervation	Action
THENAR MUSCLES				
Abductor pollicis brevis.	Tubercle of navicular, ridge of greater multangular, transverse carpal ligament.	Base first phalanx of thumb.	Median.....	Abducts and rotates thumb and extends second phalanx.
Opponens pollicis.....	Ridge of greater multangular and transverse carpal ligament.	Metacarpale I. along whole length.	Median.....	Brings first metacarpal forward and rotates it inward.
Flexor pollicis brevis....	Ridge of greater multangular and transverse carpal ligament.	Base first phalanx of thumb, with sesamoids.	Outer head median. Inner head ulnar.	Flexes and rotates first phalanx of thumb.
Adductor pollicis				
Oblique head.....	Volar surface of greater and lesser multangular and capitate bones, bases of metacarpalia II, III and IV, neighboring ligaments and sheath of Flexor carpi radialis.	Ulnar side base first phalanx of thumb.	Ulnar.....	Adducts thumb.
Transverse head.....	Volar surface metacarpale III.	Same.....		
HYPOTHENAR MUSCLES.				
Abductor quinti digiti..	Pisiform and tendon flexor carpi ulnaris.	Base first phalanx digit V., with slip to extensor tendon.	Ulnar.....	Draws little finger away from others.
Opponens quinti digiti..	Hook of hamate bone and transverse carpal ligament.	Ulnar border metacarpale V.	Ulnar.....	Draws little finger forward, narrows hand, and deepens hollow.
Flexor brevis digiti quinti.....	Hook of hamate bone and transverse carpal ligament.	Base first phalanx digiti V.	Ulnar.....	Keeps phalanx firmly down in grasping.
Palmaris brevis.....	Palmar fascia and transverse carpal ligament.	Skin of ulnar border of palm.	Ulnar.....	Draws up integument on inner side.
MEDIAN MUSCLES.				
Lumbricales.....	Radial sides of tendon of flexor digitorum profundus.	Radial sides of tendons of extensor communis digitorum and first phalanges.	First two by median, last two by ulnar.	Extensors of last two phalanges, flexors of first phalanges when these are semiflexed by the dorsal interossei. The first and second are abductors and rotators, the third and fourth adductors and rotators.
Volar interossei.....	Volar surface of metacarpalia I., II., IV., and V.	Bases of first phalanges digit, I., II., IV., and V.	Ulnar.....	Extensors of last two phalanges, adductors and rotators, flexors of first phalanges. The first is often described as the deep head of the Flexor pollicis brevis.
Dorsal interossei.....	Adjacent sides of metacarpals, more particularly upon those of the finger where insertion occurs.	Base of first phalanges digit. II., III., and IV., and to extensor tendon.	Ulnar.....	Flexors and abductors of first phalanges, and in slight degree rotators. The third extends last two phalanges. The first is sometimes called the Abductor indicis.

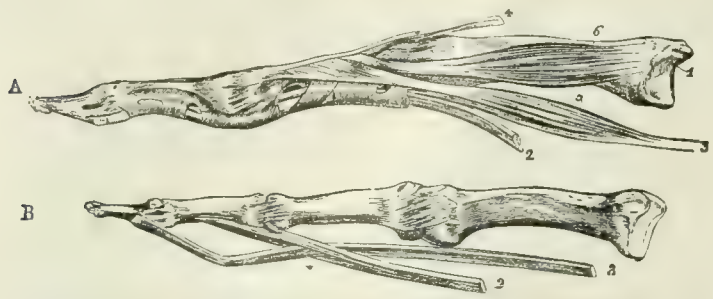

Fig. 2925. Bones of Two Fingers, with the Insertions of the Tendons (R. Quain.) In *A*, the tendons of the flexor muscles are bound to the bones by the fibrous sheath. In *B*, the sheath has been removed, as well as the vincula accessoria; 1, metacarpal bone; 2, tendon of the flexor sublimis; 3, tendon of the flexor profundus; *, perforation of the sublimis by the profundus tendon; 4, tendon of the extensor digitorum communis; 5, lumbricalis muscle; 6, one of the interosseous muscles.

Duchenne[12] noticed that in persons who were suffering from lead paralysis, and had therefore no control over the extensor muscles supplied from the radial nerve, there was still some power of extension in the second and third phalanges. The statement made in the table as to the action of the lumbricales is that of Adam,[13] founded upon observations made on the cadaver, and with electrical excitation with special instruments.

Fig. 2925 shows the manner of insertion of the lumbricales, as well as that of the interossei and the flexor tendons.

Besides the muscles mentioned in the table, the tendons shown in Fig. 2925 lie in the hollow of the hand. As they approach the fingers, the tendons of the superficial flexor lie immediately upon those of the deep, and in fact embrace them in a groove upon their under surface, this groove deepening until it at last becomes a slit through which the tendons of the deep flexor pass. It is therefore impossible to cut the tendons of the superficial flexor without at the same time cutting those of the deep flexor.

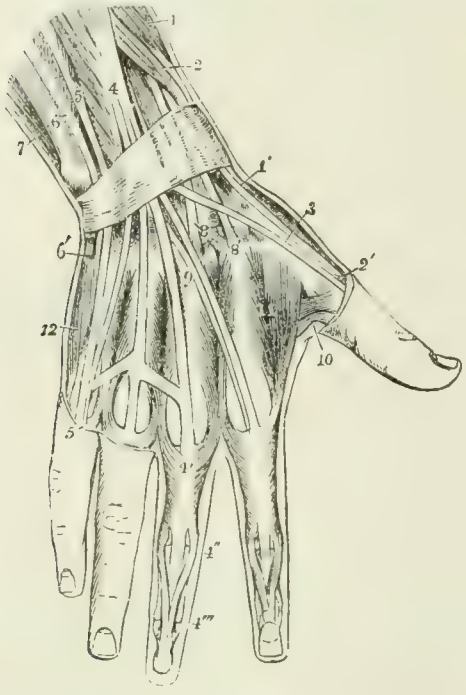

Fig. 2926.—Superficial Muscles and Tendons on the Back of the Wrist and Hand. (After Bourgery). The dorsal carpal ligament is represented. 1, Abductor longus pollicis; 1′, its insertion; 2, extensor brevis pollicis; 2′, its insertion; 3, tendon of extensor longus pollicis; 4, extensor digitorum communis; 4′, tendon of the middle finger receiving the insertion of the second and third dorsal interosseous muscles; 4″, division of the tendon into three portions, of which the median is inserted into the second phalanx, the two lateral passing on to be inserted at 4‴ into the terminal phalanx; 5, extensor digiti quinti; 5′, its junction with the slip of the common extensor; 6, placed on the lower end of the ulna, points to the extensor carpi ulnaris; 6′, insertion of this muscle into the base of the fifth metacarpal bone; 7, part of the flexor carpi ulnaris; 8, placed on the os capitatum, points to the insertion of the extensor brevis carpi radialis; 8′, placed on the base of the second metacarpal bone, points to the insertion of the extensor longus carpi radialis; 9, tendon of extensor indicis; 10, small part of the adductor pollicis, and inner head of the flexor brevis pollicis; 11, first dorsal interosseous or abductor indicis; in the other three interosseous spaces are seen in succession, from the radial side inward, the insertion of the second palmar, second dorsal, third dorsal, third palmar, fourth dorsal, and fourth palmar interosseous muscles; 12, abductor digiti quinti.

Shallow furrows appear between the tendons, and at the lower part of the dorsum the heads of the metacarpal bones become prominent. At the base of the fingers the skin becomes thinned out into an interdigital web semilunar in shape. The web between the thumb and the index finger is thicker and more marked than elsewhere, because it contains in front the adductor of the thumb where it becomes free from the first dorsal interosseous muscle, which covers it in the upper part of the interspace. As the skin and fascia on the dorsal surface of the web are thinner than on the palmar, abscesses of the palm which reach the base of the fingers usually discharge behind.

The skin of the dorsum is in many respects the opposite of that of the palm, being thin, easily movable, hairy, especially toward the ulnar side, and but slightly sensitive. Edema is much more quickly shown here, the subcutaneous tissue being loose. Numerous veins course through it and some idea can be obtained of the tonicity of the vascular walls by noting their visibility through the skin. They vary much, however, in different individuals.

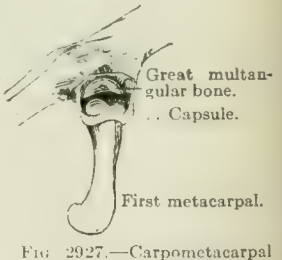

Fig. 2927.—Carpometacarpal Joint of the Thumb.

The deep fascia forms the sheaths of the tendons as they pass down. These tendons are arranged in two sets, which may be said to represent a superficial and a deep extensor similar to the arrangement of the flexors. To the superficial extensor belong the tendons of the extensor communis and the extensor digiti quinti, which pass down under the ligament almost vertically, diverging to their respective insertions after reaching the dorsum. The tendons of the communis, which go to the last three fingers, are united by oblique bands. This restricts the motion of the ring finger to a considerable degree, and it cannot be fully extended when the third or fifth digit is held firmly flexed. Subcutaneous section of these bands is sometimes resorted to for the purpose of giving pianists more independent movement of the ring finger. To the deep extensor set belong those

muscles which, arising lower down upon the forearm, run somewhat obliquely across the others to be inserted into the index finger and the thumb. These are the three extensors of the thumb and the extensor indicis. Many varieties occur which confirm this view. In apes the extensor indicis also supplies the middle finger, and sometimes the ring finger as well. The extensor longus pollicis also sends a tendon to the index, and sometimes to the medius. Similar variations occur in man. Koster[14] found the tendon of the indicis and the long extensor of the thumb united by a cross band like those which appear on the tendons of the common extensor.

The bones of the middle hand are the five metacarpals, each concave toward the palm, and having a somewhat prismatic shaft with two enlarged extremities. Closely applied at the bases they diverge along the shaft so that they never touch there, while again at the lower end they can be brought together. There is thus left room for the interossei muscles. The first metacarpal is an exception, as, in order to preserve the independence and opposability of the thumb, the base is set over and in front of the line of the others, and its distal end is not confined by ligaments. Since it is shaped more like a phalanx than like the others, anatomists have not failed to add this to other evidence which has been adduced to prove that the thumb has no true metacarpal. The joint by which it articulates with the great multangular bone is a saddle-joint, the movement being free in two planes, viz., that of flexion and extension, and that of adduction and abduction. It is not, however, limited to these, as circumduction can take place quite easily. There is no rotation. The capsule is thick and strong, and dislocation is very rare.

The situation of the joint is easily made out by running the finger upward along the shaft of the bone until it reaches the process at the base, immediately above which is the articulation. The process is made more prominent by strongly flexing and adducting the thumb, and the interarticular line can then be easily made out in most individuals. The other metacarpals are united to the wrist bones and to each other by articulations which are fixed by means of interosseous ligaments, which make their disarticulation very difficult. The fifth joint has the most movement.

The rounded distal ends of the metacarpals are of importance in forming an arch which strengthens the hand. For this reason they should, when possible, be preserved in amputating the fingers. The articular surfaces here are directed in such a manner as to have the planes of movement converge toward the middle of the hand. This greatly increases the power of grasp of the phalanges, as the tighter the fingers close the more strenuous becomes the lateral pressure. The convergence of the flexor tendons assists this. The extensor tendons pass over the most prominent part of the metacarpal heads behind. The third metacarpal, though not the longest, has its head more prominent, and is usually the one which receives injury from striking heavy blows.

The Fingers.—The anatomical names of the five digits or fingers are the pollex or thumb, index, medius or middle finger, annularis or ring finger, and auricularis or little finger, the latter presumably so called because of its use in cleaning the ear. They are of notably different length, but somewhat nicely adjusted to the functions of grasping, as will be seen on holding a ball in the hand, as shown in Fig. 2928 The middle finger is the longest and has, therefore, the longest circumference to span, and the others are so adjusted, as to length, that they come very nearly to the same level at their tips. For this reason all tools which are to be grasped by the hand should have a swelling in the handle opposite the middle, so as to insure a good grip.

The usual arrangement as to length of the fingers is that in the extended hand the thumb does not quite reach the second phalanx of the index, the medius is longer than the annularis by half a nail, and the auricularis reaches only to the last phalanx. There is considerable variation in the length of the index. In about two-thirds of the cases (Mantegazza[15]) the index is shorter than the annularis, reaching only to the root of the nail of the medius. In others the two fingers are nearly of the same length, and rarely the index exceeds the annularis in length. Ecker[16] considers the shortness of the index to be a characteristic of apes, and thinks that when relatively longer it is an attribute of a higher form of hand. He finds it longer in women, who show in this, as in many anatomical features, signs of a purer morphological form. Carus[4] does not mention the length of the fingers, but figures what he calls, after d'Arpentigny,[3] the idealistic hand (seelische Hand, main psychique), which shows a long index. It is noticed by Hyrtl[17] that the apparent length of the ring and index fingers may be influenced by the posture of the hand. If the hand is laid flat, so that the axis of the medius corresponds with that of the entire arm, the index usually appears a little shorter than the ring, but abduct the hand, and the ring finger will appear a whole nail's length longer. Grüning[18] has recently given the results of two hundred observations very carefully taken. He finds that the ring finger is usually the longer, yet the reverse is not uncommon, and more frequent in females. In the foot the second toe is usually the longest, but a greater length of the big toe is not rare, also more frequent in females. This lends some support to the theory that the foot has no digit homologous with the thumb.

Fig. 2928.—The Length of the Fingers as Adapted in Grasping. (Humphry.)

The general relation of the middle finger to the rest of the hand is expressed by Langer[10] as follows: If a measurement be taken from the capitate bone to the end of the finger, the various parts, as measured from the angles at the joints made by flexion, will be in the proportion of 8 : 5 : 3 : 2, that is to say, the middle hand is as long as the two succeeding portions, and the basal phalanx is as long as the middle and ungual together. The length of the entire hand has been used by artists as a canon of proportion for the whole body, being set at one-ninth of the whole height. The Egyptian canon seems to have been based upon the length of the index, which was reckoned as one-nineteenth of the height. Many measures used as rough estimates are taken from the hand: the length of the middle finger from knuckle to point is reckoned as one-eighth of a yard, and from the tip of the thumb nail to the second joint as about half of that, and is called one nail. The breadth of the hand is used as a measure for horses, and is reckoned at four inches. The breadth of the thumb is the pouce or inch of the old French measures. Of course all these are liable to vary because of individual peculiarity.[19]

It should be noted that the proportions of the hand to the entire height are attained very early, at least by the fifth year (Quetelet[20]). The member appears to have the same early physical development that the brain has, and the hand of the new-born child is structurally that of the adult, differing only in size.

The thumb has from very early times held the place of honor among the digits, as the loss of it deprived the hand of much of its power. It is especially by the superiority of the thumb that man's hand is distinguished

from that of the higher apes. There are no less than eight muscles attached to it, and this gives a freedom and variety of motion which is not possessed by any other digit. To cut off the thumb was an old method of disabling an enemy, by preventing him from properly using his weapons, and soldiers sometimes resorted to this mutilation to exempt themselves from

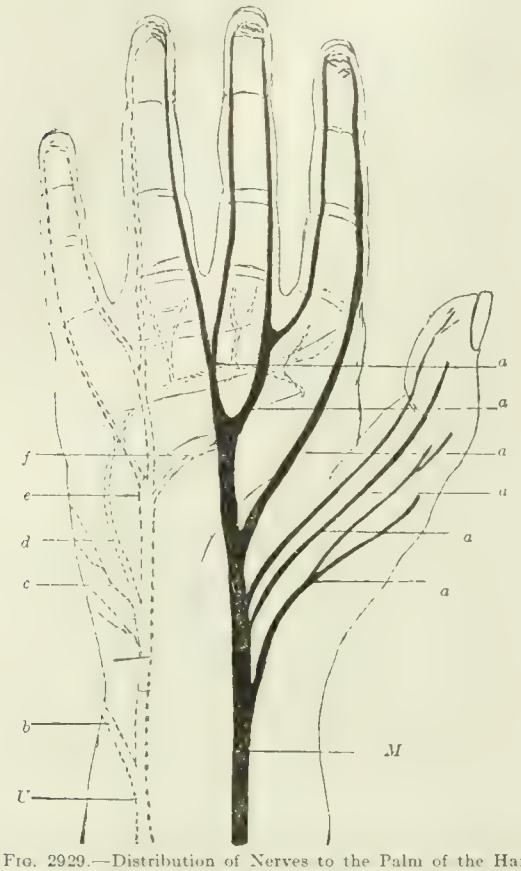

FIG. 2929.—Distribution of Nerves to the Palm of the Hand. (Tillaux.) *M*, Median nerve; *U*, ulnar nerve; *a*, *a*, *a*, *a*, *a*, *a*, collateral branches of the median nerve; *b*, dorsal branch of the ulnar nerve; *c*, muscular branches; *d*, superficial branch; *e*, deep branch; *f*, anastomotic branch.

military duty—as those of our own time have been known to amputate the terminal phalanx of the index to unfit themselves for pulling the trigger of a gun. It is from this custom that the word poltroon is said to have arisen, being a corruption of *pollice truncus*. The palmisters exalt the thumb far above the other digits. D'Arpentigny says: "*l'Animal supérieur est dans la main, l'homme est dans le pouce.*"

The Esquimaux tradition is that woman was originally formed from the thumb of man. The thumb was used by the spectators of Roman gladiatorial combats to indicate whether the conquered party should die or live. In La Vendée a large thumb indicates a predilection for the black art, and to bite the thumb is a grave insult in Scotland and Italy.*

The unusual strength of the muscles which are attached to the thumb, making it an efficient portion of a pair of forceps when applied to the other fingers, leads also to its being affected by convulsive action. In almost all cases of this kind the thumb is firmly clenched and drawn into the palm (see Fig. 2450). This may be of service as a medicolegal sign, as it is almost always found in those who have died a violent death, and consequently suffered spasmodic contraction of the muscles during the last agony.

The index or pointing finger has been called the gynecologist's eye. It is somewhat more sensitive to tactile impression than the others, and, being supplied with special muscles, it is particularly serviceable as the antagonist of the thumb. It is always best to preserve this finger and the thumb, if possible, in injuries to the hand, as by themselves they make quite a serviceable organ.

The ring finger, or annularis, is so called from the fact that it has been customary, since the time of the Romans, to carry rings upon it. This has been said to originate in the fact that they supposed it to be especially connected with the heart, either because it is supplied by two nerves (see Fig. 2929), or more probably because the vena salvatella (the largest dorsal metacarpal vein) runs prominently from it up the arm. Owing to the connection of the tendons this finger is somewhat protected by those beside it, and consequently is less liable then the others to injury, and this affords ample reason why it, as well as the left hand, should be chosen to wear the ring. The old anatomists called it the digitus medicus, because they were accustomed to mix medicines with it.

Upon the volar face of the fingers are seen certain transverse furrows, well marked. These are important guides to the joints and should be well noted (see Fig. 2923). They are not correctly given in any of the books on palmistry which the author has consulted, which shows that in point of accuracy their "science" leaves something to be desired. The folds nearest the palm are single for the index and little fingers, double for the others. They do not correspond exactly to the metacarpo-phalangeal joints, but are three-fourths of an inch below. The middle folds are double and exactly opposite the joints, the lower folds are all single and a trifle above the joints. Upon the thumb there are also three folds, the upper and lower folds correspond to the joints very nearly, the middle one having no topographical significance. The skin on the fingers is remarkably rich in papillæ; the number of these containing nerves increases as we proceed toward the finger tips. These papillæ, both on the fingers and palm, are arranged in lines forming characteristic curvilinear ridges. Upon the eminences formed by the pulps of the fingers and the eminences of the palm these are arranged in elliptical or spiral patterns, and these are used in the military and police services of America and France as a means of identifying individuals. Faulds[22] mentions that by means of finger marks upon a greasy glass it was ascertained who, among a number of servants, had been drinking some rectified spirit; and another case in which a criminal was detected by an impression of sooty finger marks on a white wall. He considers that the Mongolian races have a special and characteristic pattern. The city authorities of San Francisco recently considered the propriety of registering all the Chinese who arrived at the port by taking an impression of the thumb. It is said that the legal expression "my hand and seal," arose from the custom of sealing papers with the thumb.

Beneath the skin the subcutaneous tissue is like that of the palm—a series of little cushions of fat. On the last phalanx this is called the pulp of the finger. Still deeper is found the canal for the flexor tendons. The fibers of this sheath are less thick opposite the joints, so as not to impede flexion. They are continuous above with the palmar fascia. The canal contains in the thumb only the tendon of the long flexor, in the other fingers the tendons of the superficial and deep flexors. They are united to the sheath by small bands termed vincula. Opposite the first phalanx the flexor sublimis splits and the two halves fold around the deep flexor, again uniting behind it by their margins. They then separate and are inserted into the second phalanx (see Fig. 2925, *B*). The deep

* Vide Romeo and Juliet, Act I., sc. 2. "I will bite my thumb at them which is a disgrace if they bear it."

flexor is inserted into the terminal phalanges. Some persons have power to use it independently.

On the dorsal surface of the fingers the skin forms elliptical folds at the articulations of the first and second phalanges, and simply a few transverse folds at the articulations of the second and third. Under the skin the extensor tendons form a broad aponeu-

Fig. 2930.—The Convulsive Hand. (Warner.[21])

rotic sheet into which the expanded tendons of the lumbricales and interossei are inserted. This sheet terminates with the insertion of the extensor into the last phalanx.

The nails which terminate the digits are, as is well known, really epidermal elements. They are found in the embryo at about the third month of pregnancy. Their growth is always from the root, and the rate at which they grow can frequently be noted by the spots which occur upon them, and thus a general notion may be obtained of the vigor of the processes of nutrition.

The joints of the fingers have a general resemblance to each other, the metacarpo-phalangeal being merely a little broader. The ends of the phalanges broaden out somewhat at their extremities, and when the body becomes emaciated, as in a wasting disease, these ends

Fig. 2931.—The Hand in Fright. (Warner.)

become very prominent, and the disorder known as clubbed fingers results. At the metacarpo-phalangeal joint of the thumb there are two sesamoid bones, which are believed to be one of the causes of the difficulty of reducing a dislocation at that articulation. Similar structures, usually cartilaginous, however, are found on the palmar surfaces of each of the phalangeal joints. In negroes, or in those laborers who use the hands much for heavy work, they may all be ossified, as they are in the forefoot of a bear. The articulations are all imperfect hinge joints, having lateral ligaments and a thickening of the capsule on the palmar surface. It should be remembered that the articular line is always found beyond the angle formed by the flexion of the phalanges.

The nerves of the hand are three in number. Their distribution to the palmar surface is shown in Fig. 2929, and the muscles they supply are mentioned in the table on page 861.

To those mentioned there should be added those which come down from above. Of these the flexors are supplied by the median and ulnar, the extensors by the radial. The ulnar supplies the flexor carpi ulnaris and the principal part of the deep flexor, leaving to the median that portion which goes to the index finger, which might, therefore, properly be classed as a separate muscle.

Fig. 2932.—The Feeble Hand. (Warner.)

After section of the median nerve a considerable movement is left to the fingers, pronation being effected by the shoulder muscles acting on the arm, flexion of the wrist by the flexor carpi ulnaris, the first phalanges flexed by the interossei, the others by the deep flexor. The thumb suffers most, and we may, accordingly, say that the median nerve especially presides over the movements of that digit.

In the same way as motility is not entirely lost, so also is sensibility retained to some extent. The anesthesia does not correspond with the distribution of the nerve. The reason for this is believed to be found in the collateral branches which run from the ulnar to anastomose with the median. There is no doubt that the anesthesia after section continues to grow less, and it has been suggested that when certain parts are disabled, other nerves may send out filaments from the fine plexus into which the nerves break up before going to supply the papillæ, in order to supply the need.

The correlative action of the muscles and nerves has a very marked result upon what may be called the physiognomy of the hand. Warner[21] has carefully studied this subject, and describes, among others, the following types, which relate to the expression of the emotions: The convulsive hand (Fig. 2930), in which the thumb is forcibly and violently adducted, the fingers are pressed closely together and semi-flexed on the thumb, the hand assuming a conical shape. The opposite of this is the hand in fright (Fig. 2931), the phalanges and the wrist being extended. The whole attitude is that of repelling an abhorrent object. In pure horror, not accompanied by fear, the hands are thrown widely back, the arms uplifted, the fingers open. A passenger upon a train told me her first intimation of a fatal accident was seeing a person assume this attitude as the train shot past. The convulsive wringing of the hands is an expression of quite an opposite order, indicating intense and continued painful emotion, and instead of the hand-washing

motion performed by tragic actors, is, when genuine, a passing of one hand down the other, with a convulsive twist at the ends of the fingers.

The feeble hand (Fig. 2932) is indicated by a dropping of the thumb and a bending of the phalanges.

The tonic hand in rest (Fig. 2933) is like this, but differs in the degree of the action. The nervous hand (Fig. 2934) has the wrist slightly bent, and the metacarpophalangeal joints hyperextended, and the first and third internodes slightly flexed.

Fig. 2933 The Tonic Hand. (Warner.)

The energetic hand (Fig. 2935) is the opposite of this, the wrist being extended and the small joints in flexion.

The vessels of the hand have recently been the subject of careful study by Bourceret,[24] and he has arrived at some conclusions which seem important and new. By a very ingenious process, and using a series of injections, he has been able not only to fill the entire arterial and capillary system, but the venous system as well, injecting from the heart outward, notwithstanding the valves.

The arrangement of the arteries has already been alluded to. The radial and ulnar form, as shown in Fig. 2923, two arterial arcades known as the superficial and deep palmar arches, the first of them being made by the radial and the deep volar branch of the ulnar. To these may be added a third arch over the back of the wrist, formed by collateral branches of the two trunks. From these arches pass branches which supply the fingers, being of considerable size throughout their length, even to the last phalanges, and not

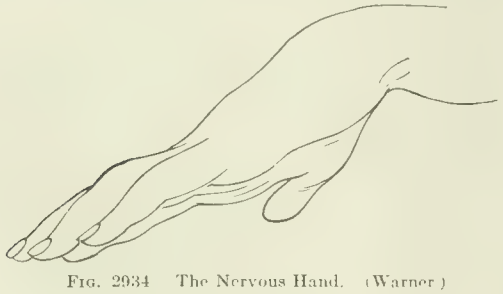

Fig. 2934 The Nervous Hand. (Warner.)

accompanied by venæ comites. The object of this excessive vascular supply is not only the nutrition of the fingers, but also to maintain the bodily warmth there. They communicate by two sets of capillaries, one small and intended for nutrition only, the other large and intended for increasing the heat. These capillaries are arranged in very complicated tortuosities, like little balls of tangled thread. They open immediately into the veins, which are also remarkable for their flexuosities.

Any consideration of the hand would be incomplete without some remark concerning the separate use of the two hands. Right-handedness, or rather right-sidedness, for the matter is not by any means confined to the hand, is the rule among all races of men, and some traces of it may be seen in the animal creation. The elephant, for example, is said to use the right tusk more than the left, and this is accordingly called the servant tusk.[25] Left-handedness is the exception, occurring in about nine per cent. of individuals. Many attempts have been made to explain this, and Franklin's[26] plea for the left hand, and Charles Reade's essay[27] upon the injury mankind inflicts upon itself by the continuous use of the right, are well-known curiosities of literature. It appears, however, that there is reason to suppose that we have, in dextral preference, merely a further differentiation like that which has resulted in the development of the feet and hands from four originally similar organs. The left hemisphere of the brain appears to be assuming control of the more complicated motor functions performed by the right side of the body, while the right hemisphere attends more especially to the nutritive functions through the sympathetic system. It is noted that the senses of temperature and of weight are usually more acute in the left hand. Perhaps this is in some degree due to its less frequent use. Granting this, we have to search for the origination of the tendency. Hyrtl[17] supposes it to arise from the fact that the innominate artery carries more blood to the right side. Dwight and others[28],[29],[30] think it depends upon the situation of the left carotid at the top of the arch, surmising that it receives a swifter current of blood, which goes to the left brain, controlling the left side. Blumenbach supposed that it was due to a deviation of the innominate artery to the left. Breschet

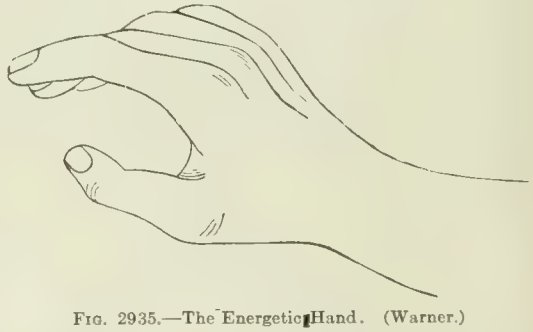

Fig. 2935.—The Energetic Hand. (Warner.)

thought that there was an innate tendency to a predominance of nutrition on the right side in fetal life. The right side of the spine develops first and so throws the heart to the left. Comte[31] suggests that it is due to the fact that the fetus in utero lies usually on the left side, owing to the obliquity of the pelvis, and that this occasions a precocity of development of the right side. The percentage of left-handed persons is about that of presentations where the fetus lies on its right side.

An ingenious explanation is offered by Buchanan,[32] who holds that the center of gravity lies on the right side owing to the weight of the liver, and that this causes a greater development of the muscles there. It is possible that several of these causes may have had an effect upon the matter. An efficient cause may be found in the situation of the heart upon the left side. A savage soon learns that his enemy is vulnerable there, and takes pains to protect himself by withdrawing the left side and using the weapon with the right. The constant persistence of this use of the right arm as the weapon-bearing member has probably resulted in organic dextral preference, and left-handedness may be considered an atavism.

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Hands and Fingers, Diseases and Deformities of the.—The hand, from its exposed situation from the great diversity of uses to which it is put, and from its great distance from the circulatory and nerve centers, together with the exposed nature of its communication with them, presents for study a great variety of lesions. The first factor is responsible for many mechanical injuries, and for injuries by heat and cold, the second for many mechanical injuries and infections. The third factor causes the hand to suffer not only from injuries and diseases of its own, but also from those of any portion of the vessels and nerves between it and the heart, spinal cord, or brain.

The hand is the weapon of offense and defense, voluntarily and involuntarily. If a blow be aimed at the head or body, the hand and arm are interposed, and suffer. If we slip and fall on an icy pavement, the hand is interposed, and we suffer, not a fracture of the coccyx or ischium, but a fracture of the radius or carpal navicular.

Upon the precision, quickness, and dexterity of the hands in offense and defense depended the very existence of our savage ancestors. To this day the vast majority of human beings depend upon their hands for their daily bread. The hands not only reflect the wear and tear of occupations, but are greatly exposed to infections and injuries. As we rise in the scale of comfort and luxury, the hands become of less use, until among the very wealthy they are employed for little else than conveying the food to the mouth, and for purposes of entertainment. Among this class infections and injuries are rare.

The affections of the hand and fingers include those that are peculiar to or affect this region exclusively; those that may occur elsewhere, but show a predilection for, or exhibit special features or modifications in, this locality; those conditions affecting the hands equally and indifferently with other parts of the body; and the manifestations, exhibited by the hand, of general disease. The conditions of most pertinence to the present subject are those more or less peculiar to the hand or those which exhibit special features in this locality.

It is not easy to formulate a completely satisfactory and logical classification of all the affections of the hand and fingers on any uniform basis. There are several grounds on which classification may be based, but no one of them alone in the present state of our knowledge is sufficient to afford a practical and adequate classification.

Congenital and Developmental Anomalies.—The class of developmental anomalies in general should include all aberrations or faults of development manifesting themselves at any time during the period of development, including not only conditions arising in the prenatal period (as polydactylism), but also those that make their appearance in childhood and up to the time of maturity and complete physical development (as certain forms of hammer finger). In this section it is proposed to consider only certain congenital abnormalities of the hand which develop during the intrauterine period of existence.

The anomalies of development under consideration embrace the following conditions:

1. Conditions in which there is a deficient degree of development, either (*a*) a deficiency in the *number* of the structural parts affected, or (*b*) a deficiency in their *size*. The congenital numerical deficiencies pertaining to the hand are: *acheiria*, in which the hand is lacking altogether; *ectrodactylism*, in which one or more fingers are missing; and *hypophalangism*, in which the number of phalanges in a digit is below the normal. The congenital deficiencies in size of the hand and fingers will be considered in connection with microcheiria and microdactylism.

2. Conditions in which there is an excessive development; either (*a*) an excess in the number of structural parts, *polycheiria*, *polydactylism*, and *polyphalangism*, or supernumerary hand, fingers, and phalanges respectively; or (*b*) a congenital excess in size, or hypertrophy, which will be considered in connection with cheiromegaly and dactylomegaly.

3. Conditions of perverted development (qualitative or morphological rather than quantitative); as syndactylism, the union of fingers; cleft hand; congenital constrictions; deflections of the hand and fingers (club hand, etc.); congenital dislocations; congenital neoplasms; and various unclassifiable deformities and conditions.

In many cases anomalies of the types mentioned exist separate and distinct; in many other cases anomalous conditions of different types are associated and coexist in the same member, as where a supernumerary finger is of rudimentary structure, or a club-hand is ectrodactylous.

Subjects exhibiting congenital anomalies of the region under consideration, especially numerical deficiencies, often exhibit other developmental faults

or abnormities in other parts of the body, as harelip or cleft palate, thus testifying to the existence of a deep-seated and general developmental vice. Such anomalies of the hand are especially associated with corresponding anomalies of the foot. In many cases hereditary transmission of the deformity is marked.

The causes of these congenital anomalies are obscure. They arise largely from deep-seated and innate tendencies to aberrant development, often hereditary.

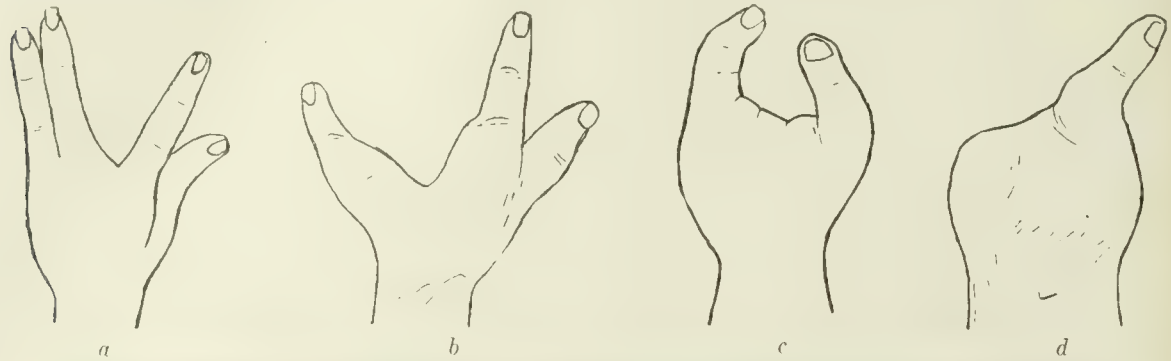

FIG. 2936.—Ectrodactylism. *a*, Congenital absence of middle finger (Fort). *b*, absence of middle and ring fingers (Clutton); *c*, absence of index, middle, and ring fingers—"pince de homard" (Annandale); *d*, absence of four digits (Annandale.)

The aberrant tendency is sometimes very definite and fixed, precisely the same abnormity appearing in different generations. Some cases may perhaps be due to abnormalities of the early environment of the developing embryo.

Another class of causes that produce congenital deformities of the hand is to be found in intrauterine trauma, or other prenatal pathological processes. Thus, intrauterine amputation may cause loss of the entire hand or parts of it; prenatal ulcerations may be followed by abnormal union or adhesions of parts, as in some cases of syndactylism; deformities may perhaps arise from cicatrization or from adhesions to other parts of the fetus or afterbirth, or in other ways.

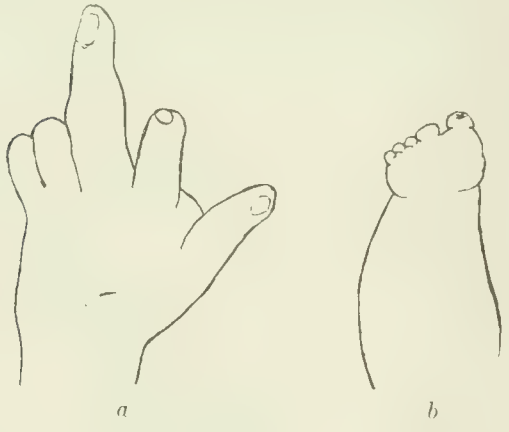

FIG. 2937—Hypophalangism (Annandale.) *a*, Absence of distal phalanges of three fingers. *b*, absence of al the phalanges of all the fingers.

Deformities caused by such prenatal morbid conditions are, of course, not real developmental aberrations; but as the results produced in the two ways are rarely distinguishable they may be considered together.

Maternal impressions during pregnancy are sometimes adduced in explanation of congenital anomalies of the hand (as elsewhere); as in the alleged case of an officer's wife, who after her husband lost his right hand gave birth to children exhibiting the same deformity. It is very doubtful if maternal impression really plays any part in the production of such deformities. Some alleged instances are coincidences; others are afterthoughts, a past incident being recalled after the birth of an affected child. Considering the difficulty that is found in demonstrating the hereditary transmission of acquired characters, it is obvious that to prove that a developing fetus can be influenced by maternal impressions is a matter of far greater difficulty.

The use of the *x*-rays now affords means of investigating and diagnosing the precise condition of the bony parts in these deformities that were lacking to the early observers.

Acheiria, or total congenital absence of the entire hand, occurs very rarely. It might arise either as a developmental abnormity or from intrauterine amputation. It would naturally occur in connection with a greater or lesser deficiency in development of the upper extremity, as when the limb is entirely wanting (ectromelia) or is partly wanting (hemimelia). When the upper extremity is only partly developed, it is more usual for a rudimentary hand, or one or more fingers, rudimentary or well developed, to be present on the stump than for all trace of a hand to be absent. Typical acheiria may, however, occur, as in a case reported by James Finlayson.[1]

Phocomelus is the rare condition in which the hand (or foot) is attached directly to the trunk, like the flipper of a seal, the upper (or lower) extremity being absent or extremely abbreviated.

Ectrodactylism consists in the congenital absence of one or more fingers (or toes), resulting from either defective development or intrauterine amputation. It is one of the less common forms of congenital abnormity of the hand, occurring considerably less frequently than polydactylism or syndactylism. In the cases that do occur both hands are usually affected simultaneously; less commonly either hand may be affected alone. Other deformities of the hand or upper extremity, or of the foot or other parts of the body, are apt to coexist with ectrodactyly. The finger involved may alone be wanting, the corresponding metacarpal bone being present; or the metacarpal bone may also be lacking; even the corresponding portion of the carpal bones is sometimes wanting. Owing to the association of other deformities and abnormal conditions the fingers present may be useful and functional, or not. The influence of heredity in reported cases is well marked. Some cases of apparent ectrodactylism may arise from intimate union of two digits.

Any of the fingers, and from one to four in number, may be lacking. The particular fingers that may be involved, and the extent to which the metacarpus and carpus may be affected, give rise to an indefinite number of possible combinations that may occur.

There are two or three particular conditions that occur with such comparative frequency, however, that they may be specially mentioned.

In a considerable proportion of cases the thumb alone is missing. This occurs especially in association with congenital absence or deficiency of the radius. Non-development or partial development of the radius is in nearly all cases accompanied by absence of the thumb, its metacarpus, and one or more of the corresponding carpal bones (Figs. 2946, 2947, 2948). In the case of absence of radius illustrated in Fig. 2948, there is a rudimentary thumb present, but articulated to the head of the metacarpal bone of the index finger.

Fig. 2938.—Double Hand. (Clutton.)

It is rare for any of the digits other than the thumb to be lacking alone, *i.e.* it is more common for two or three fingers to be absent than one of them only.

One of the common forms of ectrodactylism consists in the absence of the index, middle, and ring fingers. This leaves the thumb and little finger often opposed to each other, somewhat like the jaws of pincers; the term "pince de homard" (lobster claw) has been applied to this particular condition (Fig. 2936,*c*).

Little can be done in the way of treatment to improve ectrodactylism, unless by amputation or other operation an unsightly deformity may be removed or some impediment to function obviated.

Hypophalangism is the congenital absence of one or more phalanges and the corresponding soft parts from a digit. It is an abnormity of somewhat similar character to ectrodactylism, but the deficiency is less in degree. In hypophalangism either one, two, or all three phalanges may be lacking, the finger in the cases in which all three phalanges are missing (Fig. 2937,*b*) being represented simply by a rudimentary nodule of soft tissue perhaps surmounted by a nail. When all traces of the hard and soft tissues of the finger are lacking, the condition becomes one of ectrodactylism. Hypophalangism is a very rare deformity, and may occur in association with polydactylism or ectrodactylism, supernumerary fingers being often only partially developed. The condition is one form of brachydactylism or short finger.

Congenital anonychia or absence of the nails will be spoken of in connection with the affections of the nails.

Polycheiria, or *supernumerary hand* (double hand, dicheiria, also called, not very aptly, bifurcated, or bifid, hand). The development of a supernumerary hand, in addition to the normal hand, is a conceivable condition, but is exceedingly rare. A very few cases are on record which may be classified as double hand, though such cases merge into polydactylic conditions. In these cases the double hands each possessed from eight to twelve fingers in all; the two hands, which were not normally developed, were either united more or less along the adjacent sides, or the two parts were separated by a bifurcation extending to the carpus. Each hand had its own set of muscles and tendons, so that the two parts could close over and grasp each other; this feature is a distinguishing characteristic between double hand and simple polydactylism. The only treatment called for is the removal of useless or unsightly digits to improve the appearance or function of the member.

Polydactylism, or *supernumerary finger* (or toe), is the presence on the hand or foot of more than the normal number of digits. The supernumerary fingers vary in the degree of their development from those that are rudimentary to those that are quite perfect and well developed. This is one of the commoner of the developmental anomalies of the hand. More often there is only one supernumerary finger, but a greater number may be present. One case is recorded in which the subject possessed thirteen fingers on each hand and twelve toes on each foot; another case had twelve fingers on each hand; several cases of ten fingers on the hand have been observed and from that number down the cases become more numerous. It is more usual for both hands to be affected together than for one hand to be involved alone, and the feet are apt to exhibit a corresponding abnormality.

Syndactylism is sometimes associated with polydactylism. Hereditary transmission has been observed in numerous cases. The cause of the anomaly evidently rests in an innate aberrant developmental tendency.

All the parts that enter into the structure of normal fingers may also be present to a greater or less degree in supernumerary digits, bones, joints, tendinous and muscular attachments, nails, etc. The perfectly developed supernumerary fingers are as complete and mobile and useful in all respects as the ordinary fingers; from this perfectness the degree of development ranges down to rudimentary structures which are distinguishable from congenital tumors only by the presence of bony or cartilaginous tissue or a rudimentary nail. The muscular connection and the movability and functional value also range from a good degree of usefulness down to immovable and useless digits.

There is an indefinite variety in the possible forms and combinations in which the deformity may be manifested. Thomas Annandale's classification, which seems as satisfactory as any proposed, is as follows:

1. Cases in which the supernumerary digit is a rudimentary and deficient structure attached to the hand or another digit by soft tissues or a narrow pedicle and without any articulation (Fig. 2939,*a*). The most rudimentary of this class of supernumerary finger may practically amount simply to a tumor, the digital nature of which is shown only by the presence of bony tissue in its interior or a rudimentary nail. Supernumerary digits of this kind are usually situated on the ulnar side of the hand or little finger, but they occasionally occur on the radial side or any other portion of the hand. These digits usually have very little mobility or functional action.

2. Cases in which the supernumerary digit, more or less well developed and free in its distal portion, is given off from and articulates with the side or head of a metacarpal or phalangeal bone belonging to a normal digit, or common to the two digits (Fig. 2939,*b*). Some of these cases appear as if a finger were bifurcated, the two divisions being nearly equal and symmetrical: in other cases one of the digits from its less development or asymmetrical position is evidently supernumerary. Often the extra digit is not very movable or useful, but sometimes it has good functional power.

The supernumerary digit may articulate with (*a*) the side of the metacarpal or phalangeal bone common to it and the normal finger, in which case it has its own articular and synovial structure entirely distinct

from the corresponding articulation of the normal finger; or it may articulate with (*b*) the head of the common metacarpal bone or phalanx. In the latter case there may be two separate articulations, with separate joint cavities, or there may be only one synovial cavity common to the articulations of the two digits. Sometimes the metacarpal or phalangeal bone to which the two digits are attached bifurcates and has a separate articulation on each of the two heads. It is important to bear in mind the nature of the articulation in amputating in these cases.

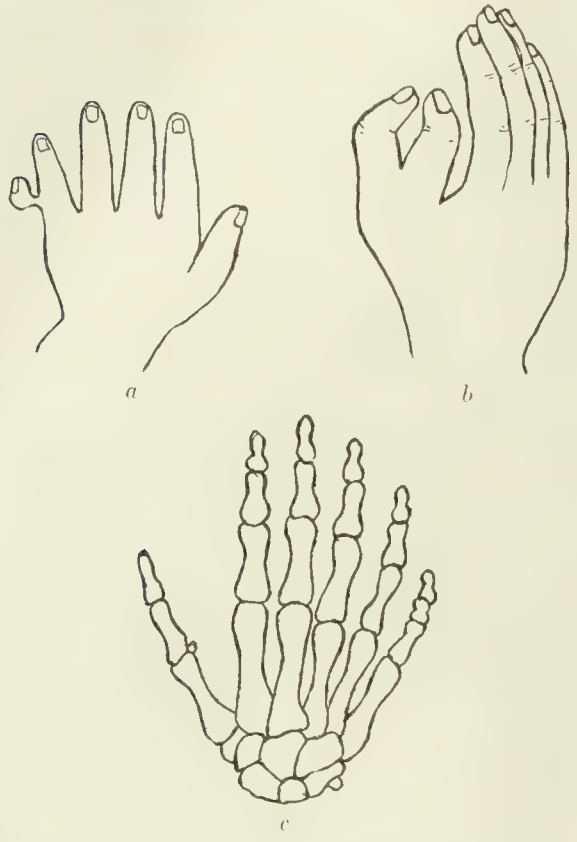

Fig. 2939.—Polydactylism. (Annandale.)

The thumb is not uncommonly the seat of this form of polydactylism, being either bifurcated (Fig. 2939, *b*) or giving off a supernumerary thumb from its side.

3. Cases in which the supernumerary finger is a practically perfect and fully developed digit, complete in itself in all its parts, and distinct from the other fingers, having its own phalanges, metacarpal bone, and attachment to the carpus (Fig. 2939, *c*). Such fingers are usually as useful and good as the normal fingers. Some cases of double hand may be partly regarded as instances of this form of polydactylism. Supernumerary fingers in rare instances are associated with a corresponding excess of development in the forearm, as with a supernumerary radius.

4. Cases in which the supernumerary digit is intimately united along its whole length to the normal digit—that is, a combination of syndactylism with polydactylism. The supernumerary digit may be more or less well developed, having separate metacarpal and phalangeal bones of its own, or possessing only phalanges which are articulated to the metacarpal bone or a phalangeal bone common to it and the normal digit. Such a double finger is broad and is apt to possess two nails. The thumb is said to be oftenest affected in this manner.

The treatment of polydactylism consists in amputation of the supernumerary digits for the purpose of improving the appearance of the hand or removing useless structures that may be an actual impediment to the function of the hand or impair its proper development. As a supernumerary digit tends to retard and impair the development of the normal finger to which it may be attached, amputation should be performed as early in life as is practicable and convenient. In some instances there had been observed a tendency for new rudimentary digits to grow out from the stumps of amputated supernumerary fingers.

In considering and practising amputation, however, careful attention must be paid to the danger and consequences of injuring a joint of one of the normal fingers and thus causing an ankylosed and stiffened digit that may be worse than the original polydactylic condition. When the supernumerary finger is connected by soft tissues only, or has its own distinct and separate articulation and joint cavity, the operation is simple and devoid of evil consequences if properly carried out so as not to interfere with other joints. But in those cases in which the extra digit has an articulation in common with the normal digit or articulates

Fig. 2940.—Polyphalangism, the Thumb Possessing a Supernumery Phalanx. (Annandale.)

with the common carpal joint, it must be remembered that the process of disarticulation will necessarily cause an opening to be made into the joint of the finger that is to be left, thereby rending it extremely liable to ankylosis. In such cases it may be preferable to amputate by cutting through the base of the bone near the joint, but without opening the joint itself. This will necessitate leaving a small portion of the proximal end of the supernumerary digit, but any slight deformity thus occasioned may be preferable to the impairment of function that will be caused by a stiffened finger. In such cases the use of the *x*-rays prior to operation may afford valuable information as to the precise relations of the articulations.

Polyphalangism (or "hyperphalangism") is the very rare condition in which a digit possesses a supernumerary phalanx, or more than the normal number of phalanges (Fig. 2940). In the cases that occur the thumb is the digit oftenest affected, though cases involving the index and middle fingers have been observed. In a very few instances in which a supernumerary phalanx was present, the phalanges generally were so shortened that the condition of brachydactyly or short finger was manifested.

Syndactylism consists in the union, fusion, or growth of adjacent digits to each other by their contiguous sides. It usually arises as a true developmental anomaly from an innate aberrant tendency of growth; or it may exceptionally be acquired, either in the intrauterine period or at any time during life, from the ad-

hesion or growth together of ulcerated digital surfaces or from cicatricial contractions. The site of union may extend the entire length of the fingers; or it may involve only the proximal portion of the fingers, to a varying extent, leaving the distal portions free and separate; or, rarely (probably from the union of ulcerated surfaces), the distal portions of the fingers may be united and the proximal portions separate. The union may consist of a thin fold or web of skin stretching across, between, and connecting the two fingers, the true "webbed fingers"; or the connection may be more intimate, involving more or less of the subcutaneous and internal tissues of the fingers, ranging up to cases in which even the bones are united. Cases have been observed in which the distal phalan-

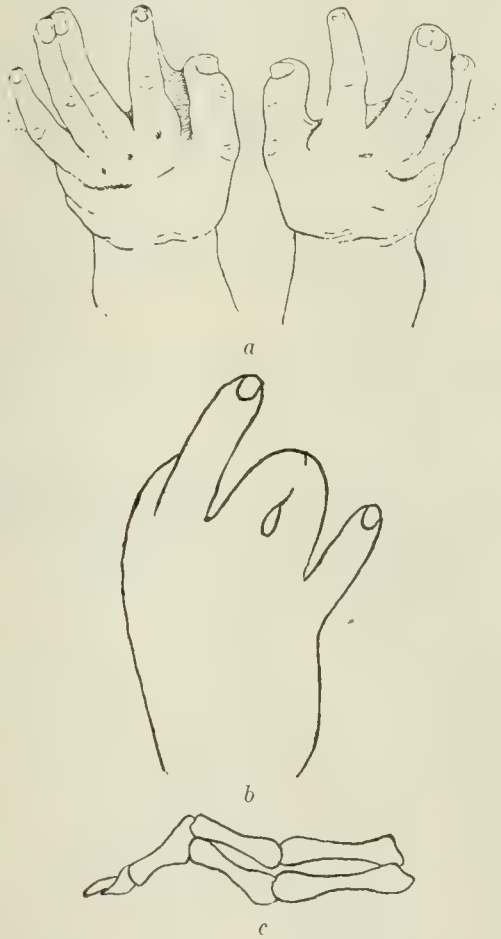

Fig. 2941.—Syndactylism. *a*, The dotted lines represent amputated supernumery fingers (Clarke); *b*, union of distal portions of fingers (Annandale, after Otto); *c*, fusion of distal phalanges (Annandale, after Otto).

geal bones were fused together, while the proximal phalanges were separate (Fig. 2941, *c*). Two fingers alone may be united, or three, or four, may be connected; rarely all the digits are bound together in an unshapely deformed mass. The index and middle fingers are not uncommonly united.

Syndactylism is not a very uncommon condition, and is one of the most frequently observed developmental anomalies of the hand. In the true congenital or developmental form of syndactylism, hereditary transmission is often observed, and both the hands are frequently involved, though the fingers affected may be different on the two sides. The hands and feet are often involved simultaneously. In acquired syndactylism heredity is of course not observable, and only one hand would ordinarily be affected.

Treatment.—The only treatment of this condition is operative. The best age for operating is usually stated as from four to six years, when the fingers are of sufficient size for easy management and control, and

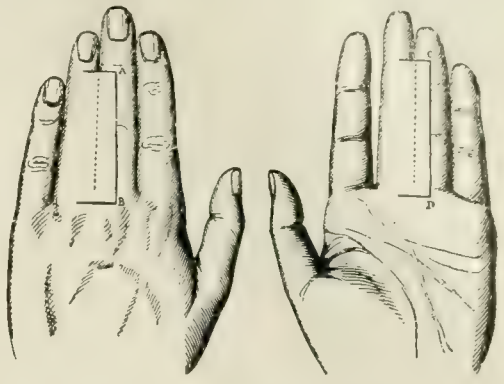

Fig. 2942.—Didot's Operation for Syndactylism, Dorsal and Palmar Views, Showing Primary Incisions.

before growth is materially interfered with by the deformity. In most cases it is easy enough to effect a separation between the digits, but to prevent the raw surfaces from growing together or to obviate a recurrence of the deformity from cicatrical contraction, is often a matter of some difficulty and requires special plastic surgical measures. It is necessary to pay special attention to the denuded surface in the interdigital angle.

When the web is broad and thin, successful and permanent separation of the united digits may be obtainable by the simple method of cutting the web in two longitudinally down its middle line, and suturing the edges of the incised skin together over each finger. The edges of the wound in the interdigital angle should especially be brought together and sutured. The fingers should, as in all operations for syndactylism, be dressed separately, so as to keep the wounded surfaces apart until healing is complete. Recurrence may, however, follow this procedure.

In some cases, especially when the union is very close, as the preliminary step in treatment, an opening may be made through the tissues connecting the digits at the proximal end of the contemplated separation. In this opening a glass or metal tube, wire, or a bundle of silkworm gut is kept until the sides of the hole heal over and become completely lined with epithelium. When this is well accomplished the fingers are cut apart for the remainder of the distance, and the edges of the wounds are approximated and sutured in the best manner practicable. The preliminary establishment of a healed surface at the interdigital angle or commissure prevents the recurrence of union from that point.

Fig. 2943.—Didot's Operation for Syndactylism, in Cross Section, Showing Method of Dissecting Off and Suturing the Flaps.

Didot's plastic operation (Figs. 2942 and 2943) appears to be the most frequently employed for syndactylism, especially for cases with a long and thick web. By this method longitudinal incisions are first made through the skin along the middorsal line of one finger and the median palmar line of the other finger

(Fig. 2942). Beginning at these incisions rectangular flaps are then dissected off, and the tissues uniting the two fingers are cut through so that one of the digits has a flap adhering to its dorsal surface and the other a flap adhering to its palmar surface. Each flap is then brought around the finger to which it is attached and its margin sutured neatly to the edge of the skin so as to cover the surface denuded by dis-

Fig. 2944.—Norton's Operation for Syndactylism. (From Bradford and Lovett.)

secting off the flaps. The method of forming the flaps and of suturing them in their new positions is graphically illustrated in Fig. 2943. This procedure keeps the healing surfaces well separated, and thus obviates readherence. It is probable that flaps should also be drawn together and sutured in some such manner as is employed in Norton's operation in order to close and cover the raw surface in the interdigital angle. From the stretching of the flaps sometimes necessi-

Fig. 2945.—Zeller's Operation for Syndactylism, Showing Lines of Incision and Outlines of Flaps. (Treves.)

tated there may at times be some tendency to sloughing of the tissues; but in general the results of Didot's operation are very satisfactory and successful.

Norton's operation (Fig. 2944), which is recommended for cases in which there is a short but ample web, consists in the formation of horseshoe-shaped flaps, dorsal and palmar, which are stretched and sutured together so as to cover the interdigital angle. The web is divided lengthwise, and the divided edges are brought together along each finger.

Zeller's operation (Fig. 2945), which is recommended for cases similar to those for which Norton's is employed, consists in the formation of a triangular dorsal flap, which after section of the web is brought into the interdigital angle and sutured in place. Agnew's operation is similar to Zeller's.

Fowler's operation[2] is recommended for obstinate and intractable cases. In this procedure a preliminary longitudinal opening or slit is made through the web between the proximal ends of the proximal phalanges, at the site of the future interdigital angle. From the dorsum of the hand two long narrow flaps are then cut, one on each side of this opening, with their attached bases near the slit. The flaps are then twisted around a quarter of a circle and drawn through the slit so that the skin surfaces of the flap are opposed to each other and their denuded surfaces are brought in contact with the raw surfaces of the slit, with which they are designed to become united. The flaps should be long enough to project through the palmar aspect of the slit about a centimeter, and they do not require to be sutured in place. The areas left by the removal of the flaps on the back of the hand can be closed by sutures. When the wounds heal, there will be a permanent opening through the web, lined with skin. The remainder of the web is then divided, and the healed commissure will prevent recurrence of the malunion.

Cleft Hand.—The contrary condition to syndactylism, the union of parts normally separate, is cleft hand, or a separation of parts normally united. Cleft hand consists in the separation of, or division between, adjacent fingers extending farther toward the carpus than normal, that is, into the metacarpal region. It is a very rare condition, and is almost invariably associated with other developmental anomalies. In nearly every case it is associated with ectrodactylism, especially with lack of the middle finger (see Fig. 2936); other anomalies, as syndactylism, may also be present. In a case reported by Charles N. Dowd[3] the number of fingers was normal, but there was syndactylic union of the metacarpal bones of the ring and little fingers; the unsightly appearance in this case was relieved by a plastic operation. This condition should not be confounded with dicheiria, to which the term "bifid hand" is often rather inappropriately applied.

Congenital Constrictions.—Congenital annular constrictions of the fingers, as well as of other portions of the extremities, have been observed, but are very rare. They are apparently produced by tight turns of the umbilical cord or of amniotic bands around the members, constricting the tissues; they are hence produced in the same manner as are intrauterine amputations but with the constriction not carried to a sufficient degree to cause complete amputation.

Club Hand.—This term in its most general sense could be applied to all deflections of the hand at the wrist joint, congenital or acquired, but as ordinarily used it is chiefly employed to designate only the congenital forms of the deformity.

The cases of congenital club hand, which is a rare condition, may be divided into some three classes, as follows:

1. The first class comprises those cases depending on contractions and altered anatomical conditions of the carpal structures in a manner entirely analogous to congenital club foot. This form of congenital club hand is exceedingly rare, as the hand is very little subject to the developmental anomalies and intrauterine conditions that give rise to talipes.

2. Of the rare cases of congenital club hand that do occur, the largest proportion consists of anomalies associated with developmental deficiency or absence of the radius. This and the following class of deformi-

ties are caused by conditions quite different from those that give rise to ordinary talipes; the term club hand is, however, generally extended to the cases associated

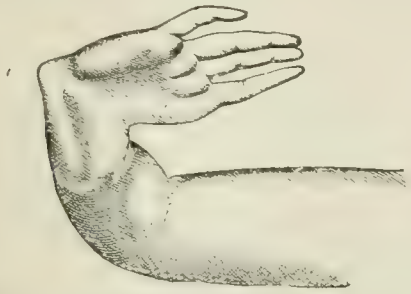

Fig. 2946.—Congenital Club Hand, with Absence of Radius and Thumb. (Hoffa.)

with defective development of the bones of the forearm. In this form of club hand the radius is either totally absent or only partially developed, the distal extremity being deficient in the latter case. The

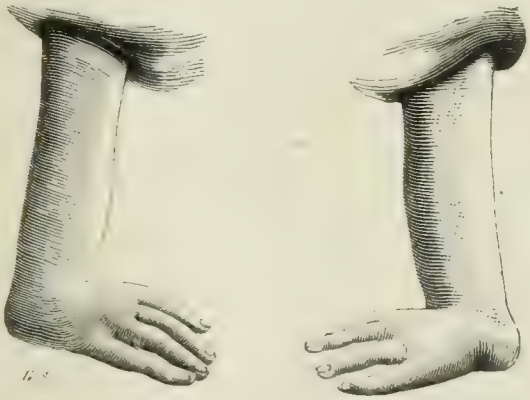

Fig. 2947.—Congenital Club Hand, with Deficiency of Radius Dorsal View.

hand is articulated on the lateral aspect of the ulna in the position of manus vara (Figs. 2946, 2947) at a considerable and even a right angle to its normal situation. The thumb and corresponding carpal bones are

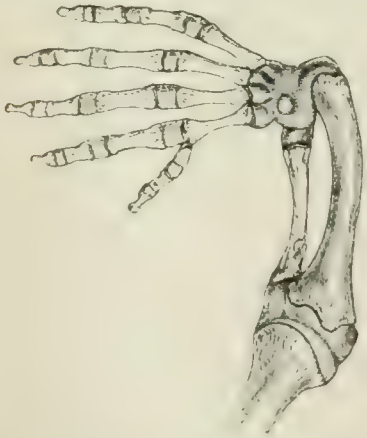

Fig. 2948.—Club Hand, with Deficient Development of the Radius and Rudimentary Thumb. (Clutton.)

usually lacking, though exceptionally present, as in Fig. 2948, in a rudimentary condition and transposed situation.

3. Much more rarely than the radius, the ulna is absent or defective, giving rise to an abnormal position and ectrodactylic condition of the hand corresponding to the radial deformity.

The treatment of congenital club hand, if undertaken sufficiently early in life while the joint structures are pliable and adaptable, consists of gradual correction of the deformed position with maintenance of the hand in the improved position until permanent results are attained. Violent and abrupt measures are not generally desirable, but the correction should be

Fig. 2949.—Club Hand, with Congenital Absence of Radius and Thumb. (Clutton.)

accomplished by gradual steps, apparatus, splints, or plaster-of-Paris dressings being employed in the intervals to maintain and render permanent each step gained. Results of any form of treatment are not very satisfactory.

In older patients the joint is apt to become so fixed that attempts at correction of the deformity may result in impairing the usefulness of a hand, which, though deformed and unsightly, still has good functional power and is a useful member. Treatment in such cases should be very conservative, and utility should not be sacrificed for the sake of appearance.

Fig. 2950.—Congenital Radial Deflection of Distal Phalanx of Thumb. (Gross.)

Deflections of the Fingers.—*Lateral deflections* may be congenital and developmental, or acquired. The acquired forms arise chiefly from cicatricial contractions, joint changes (especially chronic arthritis), dislocations, injuries, ankylosis in malposition, senile changes, or in association with hypertrophied fingers. Of these a general deviation of the four ulnar fingers toward the ulnar side is a common and characteristic condition in certain senile and rheumatoid cases.

A small number of cases has been reported in which the distal phalanx of the thumb has been congenitally

bent laterally, either to the ulnar or to the radial side, at a sharp angle. Some of these cases were hereditary, others were associated with other deformities, as club foot; the cause of this abnormity is hence developmental. The treatment, if undertaken sufficiently early, should consist in gradual correction of the deformity and fixation by splints until permanent improvement is obtained. Removal of a wedge-shaped piece of bone from the phalanx has proved successful in one case; while division of the lateral ligament and exsection of a portion of the head of the phalanx did not give satisfactory results in another instance.

There is another well-marked class of lateral deflections of the phalanges, affecting chiefly the little fingers, which occurs occasionally, often associated to a certain degree with hammer finger. Exceptionally the deflection may be toward the ulnar side, or the middle phalanx may be the one bent, or the ring finger, or some finger other than the little finger, may be affected; but usually this abnormity manifests itself as a radial deflection of the terminal phalanx of the little finger (phalanx vara). The deviation is not generally more than about twenty-five or thirty degrees, and both little fingers are usually affected together. This lateral phalanx deflection is not infrequently exhibited by little fingers that are also affected with the condition termed hammer finger. Radial deflection of the distal phalanx of the little finger is said to be common in idiots of the so-called Mongol type. The condition is of developmental origin caused by irregular development of the phalangeal articulation. The abnormity is somewhat unsightly, but is not troublesome in any other way. The only advisable treatment is the use of splints for a time to straighten the finger.

Backward Deflections (digitus superextensus).—Superextensions of the fingers or phalanges are among the less common of the deflections of the fingers; they are mostly acquired, and are due to various conditions.

The terminal phalanx of the thumb in many persons is capable of extension backward from the straight line to a marked degree, flexion not being interfered with; this is a normal developmental condition. The terminal phalanges of the other fingers are occasionally markedly extensible backward, and in such cases power of flexion is sometimes somewhat impaired.

Cicatricial contractions following dorsal ulcers, contractions of the dorsal digital fascia, joint lesions like chronic arthritis, adhesions of extensor tendons, section of flexor tendons, spasms of extensor muscles, paralysis of flexor muscles, are the other principal causes of superextended fingers or phalanges. In a considerable proportion of cases of hammer finger there is a superextended condition of the proximal phalanges of the affected fingers; and superextension of the distal phalanges in hammer fingers has been observed. In dactylomegaly there is not infrequently phalangeal superextension.

The treatment of digital and phalangeal superextensions must be guided by general principles and the conditions present. Some cases will hardly require treatment, others are susceptible of improvement. Gradual or forcible correction of the deformity with fixation by splints, division of contracting tendons or fibrous bands, or lengthening or shortening of tendons by plastic procedures may result in lessening the deformity and impairment of function.

Microcheiria and Microdactylism.—An abnormally small size of hand or fingers may be due to retarded, deficient, or arrested development, or to atrophy or retrogression after full development has been once attained. Both congenital and acquired cases are distinguishable.

Brachydactyly, or short finger, is a form of microdactyly in which the deficiency in size affects especially the length of the finger.

In dwarfs and in conditions like achondroplasia, the hand and fingers are small but not diminished in size in proportion to the rest of the body or of the upper extremity; such cases are hardly to be classed as real microcheiria or microdactyly, in which the small size is relative as well as absolute.

Brachydactyly is caused by congenital absence of phalanges (hypophalangism) or by abnormal shortness of the phalanges or metacarpal bones. Cases have been observed in which a supernumerary phalanx even was present, but with sufficient abbreviation of the phalanges to constitute a condition of brachydactyly. Brachydactyly and other forms of congenital microdactyly are rare. Deficient size of the thumb, apparently developmental, occurs in a certain proportion of the cases of ossifying myositis; in this disease a corresponding anomaly of the great toes occurs much more frequently. Fingers associated with developmental abnormities, such as supernumerary or syndactylic digits, are apt to be retarded or stunted in development unless the impediment is early removed. Injuries or diseases affecting digits during the period of development, in infancy or childhood, may arrest or retard their growth so that they may not attain full development. Loss of tissue or destruction of bone from injuries, inflammation (tuberculosis, etc.), ulceration, and the like, will if not replaced result in diminution of size. After full growth is attained atrophy and decrease in size may result from injuries, local disease, trophic influences from nervous lesions, etc.

Macrocheiria and Macrodactylism.—The following are some of the other terms applied to hypertrophy of the hands or fingers: cheiromegaly, dactylomegaly, megalodactylism, or macrodactylism.

Congenital and Idiopathic Hypertrophy.—The fingers, hand, and more or less of the upper extremity are sometimes the seat of a peculiar hypertrophy, which, though rare, presents a well-marked clinical type. This hypertrophy is of the same general nature as the condition called "congenital hypertrophy" which affects various other parts of the body, though the fingers are a favorite seat. Sometimes other parts of the body are affected along with the hand, as in the unilateral hypertrophy where the upper and lower extremities on the same side are enlarged.

When the upper extremity is involved it is far commoner for a portion only of the fingers or of the hand to be hypertrophied; very rarely the entire extremity may be enlarged. Sometimes even when there is a general enlargement of the limb, some of the fingers are relatively much more enlarged than the others.

The hypertrophy is often, though not always, manifest at birth, the affected fingers being then appreciably and materially larger than the others. Further enlargement proceeds progressively, or may take place rapidly at some time during the period of development. Cases of a high degree of hypertrophy and deformity are exhibited in young children, though the enlargement may develop even in adults. The cause of the hypertrophy is apparently some idiopathic developmental derangement, the precise nature of which is unknown. The condition is sometimes called congenital elephantiasis, and has been thought by some to be a form of elephantiasis. Some of the cases reported, indeed, may have been real instances of elephantiasis. But if the term elephantiasis be limited to hypertrophies produced by occlusion of the lymph vessels, especially by the filaria, there is probably a genuine difference between the two conditions. Hereditary transmission of congenital dactylomegaly has not been especially noted.

The hypertrophy often does not involve all the tissues uniformly, but affects especially the bony, fatty, and vascular tissues. The bones are hypertrophied, and sometimes there are joint lesions. The adipose tissues are often relatively increased, even to the production of lipomatous tumors. Areas of excessive

development of vascular structures are frequently exhibited, in the form of angiomata, angiectases, vascular nevi, varicose veins, lymphangiomata, etc. The arteries are said not to be enlarged so much as the veins and capillaries. Muscular strength is sometimes increased, often not, but the usefulness of the member is often impaired. The skin is usually not greatly altered. Syndactylism is sometimes present. Frequently some of the hypertrophied phalanges or fingers are deflected laterally or backward, from articular changes. The metacarpal portions of the affected fingers may, or may not, partake of the hypertrophy.

The enlargement is both in length and, markedly, in thickness. Various gradations of hypertrophy may occur, from slight enlargement up to great deformity and disability. In typical cases the overgrowth is frequently gigantic, so that the member may be highly deformed, unsightly, and useless. Increase of the middle finger, for instance, to a length of thirteen, fourteen, or sixteen centimeters (six and one-half inches), and to a circumference at its base of thirty-two centimeters (thirteen inches), has been noted in more than one case. In one instance the hand weighed twelve pounds.

This hypertrophy is in the great majority of cases unilateral. In the unilateral cases the right and left hands are involved with about equal frequency, with perhaps a slight difference in favor of the right. In the bilateral cases different fingers may be affected on the two hands. The middle and index fingers are much the most frequently involved, the middle more often than the index finger. The thumb is affected in a considerable proportion of the cases, the ring and little fingers infrequently. The three radial digits are therefore much the most liable to the disease. It is more usual for two or more adjacent fingers to be hypertrophied together than for one finger to be affected alone, though any of the digits may be enlarged alone. The commonest combinations are for the thumb, index, and middle fingers, or for the index and middle fingers to be affected together, next for the middle finger to be hypertrophied alone; the other fingers and combinations are less frequently involved.

Treatment of congenital dactylomegaly: When fully developed amputation may be requisite to improve the appearance and usefulness of the hand, or to prevent the extension of the hypertrophic process to the remaining portion of the hand or limb.

An elephantiasiform hypertrophy sometimes follows healing of lupus vulgaris on the hand, from chronic edema produced by occlusion and obliteration of lymph- and blood-vessels, with tendency to recurrent dermatitis, cellulitis and lymphangitis.

Hypertrophic Pulmonary Osteoarthropathy.[4, 5, 6]—This is a rare condition in which the hands and feet, with the distal portions of the forearms and legs, undergo hypertrophy in association with chronic pulmonary, pleural, or bronchial disease, such as phthisis, tuberculosis, empyema, pneumonia, syphilitic and malignant thoracic disease, chronic bronchitis, etc., mostly conditions in which the arterialization of the blood is impaired. Adults and males are affected most frequently, though children and females are not exempt. Usually the hypertrophic condition develops insidiously but in exceptional instances it has a sudden onset and rapid development, becoming well defined in the course of six or twelve weeks.

The hypertrophic condition consists in a general and symmetrical enlargement of the hands and feet and the distal extremities of the forearms and legs, other parts of the body being scarcely affected. In the upper extremity, the lower ends of the radius and ulna, the carpal, metacarpal, and phalangeal bones may all be involved. The terminal phalanges are usually markedly enlarged, giving the digits a club-shaped or drumstick appearance. According to recent writers most of this enlargement takes place in the soft parts of the fingers. The nails are much increased in size and very convex, both transversely and longitudinally, and arch over the ends of the fingers.

Pain, sometimes severe, is present in the hands in most cases, at least at some period in the course of the disease.

Among the features by which this condition can be differentially distinguished from acromegaly may be mentioned the association with pulmonary disease, the absence of any enlargement of the bones of the head, such as occurs in acromegaly, and the bulbous enlargement of the terminal phalanges and the shape of the nail, which are not manifested in acromegaly.

The condition probably has some relationship, and is even perhaps identical, with clubbed or Hippocratic fingers.

There is no definite treatment.

Hippocratic or Clubbed Fingers.—The term clubbed finger is employed to designate conditions in which the terminal phalanges or ends of the digits are enlarged and bulbous, that is, larger than the remainder of the fingers, giving them a club or drumstick shape. The fingers in hypertrophic pulmonary osteoarthropathy and sometimes in myxedema exhibit this condition. No sharp dividing line exists between clubbed fingers and pulmonary osteoarthropathy. The term clubbed fingers is commonly used, and the term Hippocratic fingers is specifically used to designate a bulbous enlargement of the ends of the fingers, with a longitudinal curvature of the nail, that is occasionally present in chronic conditions in which the circulation is weakened, especially in pulmonary tuberculosis and heart diseases. The condition can be treated only by attention to the general disturbance which causes it.

Fig. 2951.—Hippocratic Fingers. (Meillet and Richer.)

Neoplasms.—Aside from warts, this region is not particularly prone to the development of neoplasms.

The congenital tumors of the hand and fingers compose a group of cases in which the tumor is present at birth. Neoplasms of this class that have been observed are rudimentary supernumerary fingers, dermoid tumors and cysts, fibromata, lipomata, chondromata, and angiomata. Such congenital tumors are not common.

As already stated, *supernumerary fingers* are often of so rudimentary a structure that their digital nature is shown only by the presence of a small amount of osseous or cartilaginous tissue or a nail; such structures practically amount to tumors. These are usually attached by a soft pedicle and are most commonly situated on the ulnar margin of the hand or little finger. If we conceive such structures to be still more rudimentary, lacking all traces of bony or cartilaginous tissue or nail, we will have left simply tumors composed of fibrous tissue covered with skin, and having no distinct digital characteristics. Congenital tumors of this nature have been observed, often pedunculated and on the ulnar side of the hand, and in some cases are doubtless supernumerary digits of extremely rudimentary character.

Warts—the familiar verruca vulgaris—are very common on the hands and fingers, which are their

favorite seats. They are especially common in childhood, occurring singly or in numbers. They consist of hypertrophied and elongated papillæ of the corium surmounted by thickened and horny epidermis. Among the methods of treatment may be mentioned cutting out the growth with knife or scissors and applying caustics—as silver nitrate, potassium hydrate, or chromic acid, solid or in solution—to the denuded surface.

Chondromata are the commonest (aside from warts) of the benign neoplasms of the hand and fingers. Sometimes they are congenital, sometimes result from trauma, usually arise without assignable cause. They occasionally develop in the soft tissues, but usually arise from the interior or the surface of the bones, the periosteum, or the joints. They may be firm or soft, may break down and ulcerate, and may ossify. They may be single or multiple, may involve one or several fingers, one hand or both hands. Often they attain a large size and occasion great deformity and disability, so that amputation may be required.

The *treatment* of neoplasms of the hand and fingers must be guided by general principles and the circumstances of the case. Removal or excision of the tumor or amputation if deformity is extreme are the ordinary procedures. The malignant tumors require complete removal or amputation.

Injuries.—Wounds of all kinds—incised, lacerated, contused, punctured, gunshot—are of common occurrence. Not infrequently portions of fingers or entire digits are cut or torn completely off. The treatment is that of wounds in general, the chief objects aimed at being hemostasis, asepsis, coaptation. Aseptic wounds heal well and rapidly in this situation, but if infection occurs healing may be very slow; asepsis is therefore highly important, especially after bites of animals. Tendons and nerves, if severed should be carefully sutured to avoid subsequent impairment of function. The hand should be immobilized while healing.

When portions of the fingers are entirely cut off or hang by a small neck or shred of tissue, there is some hope of obtaining complete reunion of the severed portion. The parts should be well cleaned and sutured nicely together. Well-authenticated cases are on record in which a part of a finger completely cut off has perfectly reunited to the stump when sutured back in place, so that an attempt should at least be made to save the finger in all such cases. A case has been reported in which the hand was almost severed from the forearm at the wrist, all the blood-vessels and muscles and most of the bones being divided, leaving only the ulna and a small portion of skin intact; even in this case good union was obtained with reëstablishment of the circulation and function of the hand. Such cases illustrate the advisability of conservative treatment of wounds of the hand, and of the attempt to save as much of the member as possible.

Contusions and crush injuries of the hand and fingers are very common, and exhibit all gradations from slight bruises to cases in which the hand is crushed and lacerated into a shapeless mass, as in machinery injuries. The treatment is to be guided by the circumstances, but it should be as conservative as possible, and it should be remembered that this region possesses great reparative power if uninfected. Complete destruction of the ends of the fingers by crush injuries, the nail and all the soft tissues to the bone being destroyed, may be followed by regeneration so nearly complete that scarcely any trace of the injury will be perceptible. Unlike the lower extremity, lost parts of the hand or upper extremity cannot be satisfactorily replaced by mechanical apparatus, so that in injuries every attempt should be made to save as much as possible of this useful and unreplaceable member. Parts should not be amputated unless or until it is evident that repair is impossible.

Foreign bodies, like bullets or splinters lodged in the member, *bites* and *stings* of insects, and other poisoned wounds, etc., should receive the customary treatment, infection being especially guarded against. Needles or pieces of needles should be located by the Roentgen rays taking two plates at different angles. As a rule the incision should be made at right angles to the needle, but zeal to find the foreign body must not carry the operator too far in his dissection. It were better to sew up the wound and to leave the extraction to a later time, when the needle has reached a more accessible situation. *Sprains* and *dislocations* will be considered in connection with the affections of the joints.

Fractures of the phalanges and of the metacarpals are fairly frequent, and, strange to say, are often extremely difficult to diagnose without the Roentgen rays. The former are usually treated best by extension on a splint. For the treatment of the latter much ingenuity often is required to avoid the "dropped" knuckle which causes so ugly a deformity. As a rule, bandaging the hand with the fingers flexed over a small ball or roller bandage will give the best results, if care be taken to push the fractured bone well backward dorsally.

The hand is often badly deformed and often rendered almost useless as the result of a poorly treated Colles' fracture, or a fracture of the carpal bones. The deformity following an unreduced Colles' fracture can be distinguished only by the Roentgen rays from that following an old fractured navicular with unreduced luxation of the semilunar bone.

Burns and scalds of the hand are very common, causing superficial dermatitis, ulceration, or more or less necrosis. If the destruction of tissue is extensive they are exceedingly apt to be followed by deforming and disabling cicatrical contractions.

Frost Bite.—From their small size, exposed situation, and distance from the circulatory centers, the fingers are often frozen, exceeded in their liability to this accident only by the ears and toes. Frost bite is apt to cause complete necrosis of the tissues involved, though the gangrene may be slow, even weeks, in attaining its full development. The frozen parts should at first be thawed out very slowly, as by the use of cold water, in order to avoid inflammatory reaction. The subsequent treatment is that of the necrosis which may supervene, removal of the sloughs by caustics, or excision, asepsis, and protection of the resulting ulcer; and if the gangrene is extensive enough and when the limits of the necrotic process are demarked, amputation, preserving as much viable tissue as possible.

Inflammatory Conditions.—These, which are caused principally by the pyogenic staphylococci and streptococci, occur in a variety of forms, as infected wounds, cellulitis, and abscess. In the initial stages of these conditions the morbid process may be purely inflammatory, suppuration setting in later. In some mild cases the morbid process does not pass beyond the stage of simple inflammation, and is arrested before suppuration occurs.

The simplest form of pyogenic infection is that exhibited by *infected wounds*, in which the tissues adjacent to the injury are inflamed or suppurating. In more severe cases the infection extends to tissues more distant from the wound

Erysipeloid[7, 8] is the name given to an affection of the skin, of the hands, fairly frequent in those who handle stale meats, fish, etc. Hence it is seen especially in butchers and fish-dealers. It resembles erysipelas, but is without its constitutional symptoms. It consists of a dull reddish, elevated area which tends to spread over the skin, clearing up in one locality as it spreads to another. Swelling, itching and burn-

ing may or may not be prominent. The affection is said to be due to a microorganism, and is self-limited. A satisfactory form of treatment is by ichthyol applications.

Exudative Cellulitis is an infectious condition that often involves the upper extremity. The infecting organism gains exntrance at a wound about the fingers or hands, often insignificant and unnoticed. The earliest symptom, often overlooked, is a faint red and inflamed streak, perhaps a little tender, extending from the point of infection up the arm; this is caused by an inflammation of the subcutaneous lymphatic channels, up which the infection rapidly extends. Next a large accumulation of serous fluid occurs in the subcutaneous tissues, causing a great distention and swelling of the fingers, hand, forearm, and more or less of the entire upper extremity. This lasts for several days before it subsides, and is accompanied by fever and much pain (from the tension). Sometimes the case proceeds to a general phlegmonous cellulitis, often resolution takes place without suppuration. The treatment consists in disinfection of the original focus of infection if it is discoverable; immersion of the swollen parts in cold or hot water for hours and even days to mitigate and arrest the process; multiple incisions through the skin if necessary to relieve tension and pain and allow escape of fluid; application of moist antiseptic and sedative applications; tight bandaging to keep the swelling down, etc.

Suppurative Cellulitis (phlegmonous erysipelas, abscess, etc.) is a suppurative inflammation of the connective tissues beneath the skin. It may be diffuse or circumscribed. It may involve an extensive area, with considerable danger to life, or it may be localized and confined to a small region (abscess). The portal of infection may be obvious, or the origin may be quite obscure. The process begins with a simple inflammation, gradually proceeding to suppuration; or in mild and abortive cases the trouble may at no time proceed as far as definite suppuration. The treatment, in general, is that of such conditions generally; in the early stages attempts to abort the process and avert suppuration by cold or heat. As soon as suppuration fairly sets in, free incision and open treatment of the abscess should be practised. Suppurative processes in the hand and fingers are apt to run a very slow and protracted course before final recovery.

No part of the hand is exempt from suppurative inflammations or abscesses, but certain regions are so subject to these infections and exhibit such special features that a few special forms of the inflammatory process are plainly distinguishable and require special attention, namely, paronychia, whitlow, palmar abscess.

Boils and carbuncles may occur in this situation, but the hand is not a favorite seat of these lesions.

Paronychia.—The ordinary acute paronychia, popularly termed "run-around" or "ring-around," is an inflammation, sometimes running on to suppuration, of the tissues at the sides and root of the nails. It is produced by the various pyogenic bacteria, which gain access at the root of the nail; there is also a syphilitic form of paronychia which is more chronic. The inflammation involves the cutaneous and subcutaneous tissues of the circumungual region, affecting only one finger, as a rule, at a time. At first the ordinary phenomena of inflammation are manifested—redness, pain, tumefaction. The pain and tenderness are not usually severe, but are sufficient to cause considerable annoyance and irritation. Many cases do not go beyond simple inflammation, but others proceed to suppuration, and in severe cases the nails may be cast off, and ulceration may ensue. While usually acute and of short duration, the course of paronychia may sometimes be subacute and prolonged. The inflammation is wont to be more severe and more prolonged in those of generally lowered constitutional condition or with specific taint. Paronychia is a common affection.

In the early stages, with the view of checking further progress of the inflammation and to relieve pain, applications of heat, cold, or wet dressings may be employed. When pus formation is established free incision should be practised and the lesion treated like ordinary abscesses. The trouble usually yields readily to treatment. In cases of debility or specific taint constitutional treatment may facilitate healing.

Whitlow, Felon, or Panaritium (panaris), is a localized suppurative inflammation of the tissues of the palmar portions of the digits. Abscess may affect the dorsal tissues, but is much more frequent in the palmar regions of the fingers, where it presents special features. As regards pain, duration of disability, and loss of tissue, whitlow is a condition of no little gravity. Very often there is no perceptible wound by which the infecting bacteria gained entrance. Sometimes the condition arises after a slight bruise, blister, or other trauma unaccompanied by any solution of continuity of the surface skin, a slight contusion of the tissues probably producing a local lowering of vitality and lessening of resistance that determine the development of infection at the point. A lowered constitutional condition may sometimes be a predisposing cause. Destructive processes in the fingers, often called whitlows, are generated by trophic influences in certain nervous affections, notably syringomyelia, but these have rather a necrotic character than the infectious nature of true whitlows. Any of the phalanges of the fingers may be affected, more frequently and often more seriously the distal phalanx. Only one finger is ordinarily involved at a time, and whitlow is a quite common affection.

Three groups of tissues may be involved in the inflammation—the skin and subcutaneous tissues, the periosteum and bone, and the tendons and their sheaths. The inflammatory process may originate in any of these tissues, but usually extends from one group to another. The course of the disease varies according to which phalanx is affected.

The *distal phalanges* are somewhat more frequently affected than the middle or proximal ones. If the inflammation begins in the superficial tissues the skin shows the signs of inflammation—redness, swelling, pain. If the infective process starts deeper, the skin will not itself be red or inflamed, but the subcutaneous tissues will be edematous from the inflammatory exudate, and the finger at this point will be tense and swollen and the seat of severe throbbing pain. In the distal phalanges there are no tendons and sheaths to enter into the case, but the subcutaneous fibrous tissues are intimately united with the periosteum, and inflammation of the subcutaneous tissues is almost certain to extend to the periosteum and bone, especially if thorough incision is not early practised. This involvement of the bone in the inflammatory process is what renders whitlow in the distal phalanx a rather serious condition. At first the morbid process is purely of inflammatory nature, but very early suppuration develops. Osteomyelitis sets in, and the phalangeal bone becomes carious. The course of the trouble is exceedingly slow and protracted, and weeks often elapse before healing is complete.

The fingers possess quite slight resistance and reactive powers against deep-seated suppurative processes, perhaps from the relative circulatory weakness of these distal members. Pain is marked, often excruciating. The tissues at the height of the process are boggy and infiltrated with serous and purulent fluid, and the inflammation tends to extend proximally. Owing to the frequent deep situation and confinement of the infected area, the inflamma-

tion is apt to extend deep and far, causing great destruction of important structures before it will make an opening spontaneously through the skin. Granulation is slow to develop, but when well established the sinus is in a healing condition and on the way to obliteration.

Whitlows involving the *middle* or *proximal phalanges* are rather less common and generally less serious and protracted than in the distal phalanx. In these situations the tendinous structures are interposed between the subcutaneous tissues and the periosteum and bone, and to a large extent protect the latter from involvement. The escape of the bony structures from inflammation considerably mitigates the severity of the case. The morbid process readily extends along the tendons and tendon sheaths, and from destruction of their tissue or the formation of adhesions may cause considerable permanent disability and impairment of function. Aside from the special conditions offered by the presence of the tendons and the partial protection of the bone, the clinical features of whitlow in the two proximal phalanges are much the same as in the terminal phalanges. The infection may extend greatly in the tendon sheaths if an opening is not made in time through the overlying tissues. There is special liability to extension of inflammation along the tendon sheaths of the thumb and little finger into the palm. Pain is severe and healing is slow.

In treatment of whitlows, at their very inception an attempt may be made to abort the inflammation by the application of heat or cold. Such measures will not often be successful, and if the infective process continues to advance, radical treatment should be early adopted. Deep and thorough incision into the inflamed tissues is then necessary. Mere incision through the skin is not sufficient unless the trouble is all superficial; the opening must be carried down into the focus of infection. To secure thorough opening, therefore, in the distal phalanx the incision should be carried down to the bone; in the other phalanges incision to the tendinous structures will usually be sufficient. Free exposure of the affected region relieves tension and pain and provides a sort of safety vent, tending to prevent the further deep extension of suppuration. All fragments of necrotic bone should be removed, and curetting may be necessary. If the inflammation has entered the tendon sheath, the sheath should be laid open as far as the inflammation extends. Drainage should be provided for, and the incision not allowed to close prematurely. Packing with gauze affords drainage and stimulates healing. Anodynes to relieve pain will often be required, and in debilitated patients general tonic treatment is indicated. Healing must be expected to be very slow, and some permanent deformity or impairment of the motor powers often follows.

Palmar Abscess.[9]—Abscesses in the palm of the hand often involve the sheath of the flexor tendons in this situation, either primarily, or by extension from the digital tendon sheaths or from the subcutaneous tissues and fascias of the palm. The anatomical arrangement of the sheaths of the flexor tendons in the digits and palm is an important factor in palmar abscess. In the palm is a large synovial sheath common to the flexor tendons; this is usually continuous with the sheath of the tendons belonging to the thumb and little finger; but the flexor tendon sheaths of the index, middle, and ring fingers are as a rule closed at their proximal ends and are not connected with the large common sheath in the palm. Consequently inflammation of the tendinous structures of the thumb and little finger can easily extend into the large palmar tendon sheath, and *vice versa*, while in the other three digits inflammatory processes do not so readily extend from digits to palm. In whitlows of the thumb and little finger special care should therefore be taken to prevent extension into the palm. The inflammatory process may extend widely, especially if not adequately treated, involving more or less of the tissues of the entire hand, even to necrosis of the metacarpal or carpal bones. Palmar abscess is manifested by swelling, severe pain, heat, constitutional disturbance, fever, etc. It is quite a serious condition, and may result in more or less stiffening of the fingers, permanent injury of the tendons, and impairment of the motor functions of the hand; even death may occur from exhaustion, general sepsis, or hemorrhages.

The main feature of treatment of palmar abscess consists in early and free incision, so as widely to expose the inflamed parts. Care should be taken to open the main suppurating foci, and not to stop with opening into small secondary sinuses or superficial edematous areas. Valuable information may be obtained as to the location of the process by the points of greatest sensitiveness. Radical incision relieves tension and pain and localizes the process so as to prevent further extension. Infected tendon sheaths must be freely laid open as far as the inflammation extends. Longitudinal incisions in the palm, along the middle line of the metacarpal bones, can be freely made beyond the level of the web of the thumb without interference with the digital vessels or palmar arches. Swelling on the back of the hand is often extreme, but incisions there are usually of little use. Aside from the special points mentioned and the greater area involved, the clinical features and treatment of palmar abscess and of whitlow are much the same. Few surgical affections require for their treatment greater skill than hand infections, and few receive proper treatment so rarely.

Tuberculosis.—The bones and joints of the wrist and hand are affected with tuberculosis fairly frequently. The reader is referred to the article on Arthritis for a description of the lesions.

The chief clinical forms in which tuberculosis of the skin appears in the hand are lupus vulgaris and tuberculosis verrucosa.

Lupus vulgaris affects the face most frequently, but in a considerable proportion of cases attacks the extremities, including the hand and fingers. The dorsum of the hand is the locality chiefly affected, the disease only very rarely beginning in the palm. The disease occurs or begins chiefly in childhood. It runs a very slow and chronic course, though at times it makes rapid progress. Clinically the affection arises from soft, brownish-red, painless nodules which develop in the corium singly or in coalescent aggregations and cause a slight projection above the cutaneous surface. The nodules may run their course as such, and undergo involution and absorption, leaving a superficial desquamating area and a sunken cicatrix; or they are very apt to break down and form shallow ulcers; or the affected tissues may proliferate in exuberant fungoid granulations. After pursuing an exceedingly protracted course for months or years, the ulcers may heal and great cicatrical contraction or elephantiasiform enlargement may result.

Tuberculosis verrucosa is a form of cutaneous tuberculosis differing in some of its clinical features from lupus vulgaris. It arises chiefly from direct external inoculation of the skin with the tubercle bacilli, and hence occurs mostly in adults whose occupation exposes them to the handling of infected tissues or other material. The hands and fingers, especially their dorsal surfaces, are therefore the commonest seats of tuberculosis verrucosa, though other parts of the body, as the elbows and knees, are also subject to it. The essential lesion of tuberculosis verrucosa begins as a papule in the corium, which becomes pustular, then breaks down and forms a small ulcer, upon which papillary growths develop, and after some time becomes covered with a horny

mass. The characteristic feature of fully developed verrucose tuberculosis is the tendency to horny or warty papillary proliferation. The disease extends slowly from a center.

The simplest form of the trouble is the *verruca necrogenica*, also called "postmortem wart" and "anatomical tubercle," which is a small nodule found on the fingers or hand of persons exposed to local inoculation, as physicians or nurses engaged in clinical or autopsy work.

Fully developed tuberculosis verrucosa is similar in nature, but of greater extent. In this condition there are slightly elevated horny, warty patches on the skin, varying in size from small areas to large plaques covering the entire dorsum of the hand and even extending over on the palm. The patches are aggregations of warty nodules and slowly extend at the periphery. They have an erythematous border, inside which is a zone of pustules; the center of the patch is occupied by an aggregation of warty tubercles covered with crusts and horny material. There may be erosions and fissures, but there is little tendency to ulceration. The center may undergo resolution, leaving a central cicatrix surrounded by a disease ring. The course of the disease is very slow and chronic, sometimes continuing for years. Usually the general condition is not impaired, and the lesion is not ordinarily followed by serious results; general tuberculosis may, however, originate from the cutaneous infection.

In both lupus vulgaris and verrucous tuberculosis the essential lesion is tubercle formation in the corium, and in both tubercle bacilli have been demonstrated.

In addition to these two types of cutaneous tuberculosis other clinical forms of tuberculous dermatitis and cellulitis may occur. Chronic paronychia of tuberculous origin has been observed; and some cases of "malignant paronychia," in which there is extensive ulceration and a protracted and severe local condition, are supposed to be of tuberculous nature. An inflammatory tuberculous tumor, not of warty nature, has been known to follow a slight wound on the hand caused by the thumb nail, in the case of a physician who at the time was treating two cases of tuberculous laryngitis (Schamberg).

Tuberculous dactylitis, or tuberculous inflammation of various tissues of the digits, though an uncommon condition, presents some distinctive features. Tubercle formation begins in the marrow of the phalangeal bones, especially near the articular ends; the cortical bone becomes gradually involved, while new bone is simultaneously formed by the periosteum. In this manner the phalanx assumes a characteristic fusiform shape, enlarged at its middle. Tuberculous dactylitis is quite similar in its clinical manifestations to syphilitic dactylitis, and has often been mistaken for the latter. The history (personal and family), the effects of specific treatment, etc., must be taken into account in making the diagnosis. As to prognosis, a protracted course of the disease is to be expected but recovery often results and may be usually expected if general tuberculosis does not occur.

Treatment.—In children the treatment of tuberculous dactylitis should be conservative. Cleanliness, dry dressings, passive hyperemia, etc., will usually be found the most satisfactory. Ahrens[10] has practised with good results the removal of the diseased shaft, and its replacement with a cylinder of bone from the tibia. In adults, the disease is rare, if it ever occurs. Conceding its possible occurrence, amputation is recommended. In the cutaneous forms of the disease vigorous local treatment often effects a cure. Curetting is very useful for ulcerating and granulating surfaces in conjunction with caustics like silver nitrate, arsenic, and salicylic-acid preparations. Nodular and warty lesions are well treated with thermo- or galvanocautery or puncture. Small areas may be excised, but cicatricial contraction or recurrence of the disease in the scar may follow; skin grafting may be useful treatment for ulcers following excision. Scarification in crossing series of close parallel lines has been highly recommended, but requires repeated séances and a long time.

Syphilis.—Like other parts of the body, the hand and fingers are subject to various manifestations of syphilis, both inherited and acquired forms of the disease; a few special features are exhibited in this region. The chief syphilitic lesions encountered on the hand are the chancre, various syphilides, syphilitic paronychia, syphilitic onychia, gummata and inflammatory processes in the deeper tissues, syphilitic dactylitis.

The fingers and hand are occasionally the seat of the initial *chancre*, the primary inoculation taking place at this point not infrequently in physicians from exposure to the infection in the course of clinical work, or in others, not innocently, from libidinously handling the genitals. The inoculation is apt to take place about the nails, though the chancre may be situated on other parts of the hand, and may resemble paronchyia or whitlow. The chancre is usually red, thickened, elevated, indurated, and circumscribed, but ordinarily does not show much tendency to ulceration. Its course is slow. It is followed by enlargement of the epitrochlear gland, and often of the axillary glands.

Most of the varieties of *syphilides*—macular, papular, vesicular, pustular, tubercular—may affect the skin of the hands. The palms are quite favorite seats for the development of many syphilides, especially the papular and squamous forms, and exhibit a special tendency to desquamation of the lesions. The dorsum of the hands, on the contrary, is comparatively exempt from most forms of cutaneous syphilis; the ulcerating tubercular syphilide, however, frequently involves the back of the hand. The moist syphilitic papule may affect the interdigital angles.

Owing to the more or less continuous irritation to which it is exposed, the palm (with the sole) exhibits a special form of syphilide, the palmar (and plantar) syphilide. Hence palmar syphilides are observed most frequently in those who do much manual labor. The lesions of this condition consist of irregular patches, only slightly elevated, covered with scales, beneath which is the dull red infiltrated corium. The margins of the patches are especially scaly. The patches may coalesce, forming serpiginous areas, and deep fissures into the corium may develop. Sometimes instead of desquamating the epidermis becomes hard and horny. Subjective symptoms are ordinarily absent. The lesions may occupy only a small area, or may extend over the entire palm, only rarely proceeding to the dorsal surface or beyond the wrist. They may develop early or late in the course of syphilis, are very chronic in their course, exceedingly obstinate and resistant to treatment, and show marked tendency to recurrence.

Syphilitic Paronychia, or involvement of the tissues about the nails (of fingers or toes), exhibits three chief types, a dry or corneous, an inflammatory, and an ulcerative form.

Dry or Corneous Syphilitic Paronychia, the commonest form, is characterized by a horny thickening or proliferation of the circumungual epidermis, with repeated exfoliation. It begins as a small, hard, horny mass at the side of the nail, which increases in size, and may extend entirely around the nail or even invade the entire dorsum of the last phalanx. This thickened epidermis cracks and exfoliates, leaving the surface ragged and scaly. The lesion is slightly tender and of a yellowish color. The corium is more or less infiltrated, and in bad cases may be thickened, fissured, excoriated, and painful. The nails are only slightly affected. The process is very

indolent and recurrent, and occurs in the secondary stage of the disease. Several fingers are usually affected successively.

Inflammatory Syphilitic Paronychia begins as a papule or nodule, usually at the side of the nail, sometimes over the matrix, which pursues a very slow course without active inflammation or tendency to suppuration or ulceration, and disappears by absorption. The affected area is hard, dusky red, slightly tender. Onychia only exceptionally coexists. It is often confined to a single digit. It occurs in the secondary stage, especially in those out of health and often in children with congenital syphilis.

Ulcerative Syphilitic Paronychia is a severe condition caused by a gummatous process, with necrosis, in the corium and subcutaneous tissues. It is a secondary or perhaps rather a tertiary phenomenon, and develops especially in severe neglected or debilitated cases of syphilis. It is often confined to a single finger, and is very chronic in its course. The lesion consists of an indolent ulcer with undermined edges and surrounded by a raised dusky or red border. An abundant thin seropurulent discharge is given off. From extension of ulceration to the matrix and nail bed, the nail becomes discolored, undermined, and loosened, and may be cast off. In severe cases the granulations become exuberant and fungous; the cast-off nail is perhaps embedded in their midst as an irritating foreign body; the tissues about the ulcer swell and become indurated; the entire dorsal surface of the phalanx may be invaded; and the digit may become clubbed. If the nail bed and matrix are destroyed no new nail will be formed when the ulcer cicatrizes.

Fig. 2952.—Syphilitic Onychia. (Nichols.)

In the treatment of syphilitic paronychia, mercury alone or with the iodides is indicated. Frequently the action of these remedies is much prompter if they be preceded by one or two doses of salvarsan. The iodides should be given especially freely in the ulcerative form. Local treatment should be followed according to the indications. The affected finger tips should be protected from irritatoin by finger-stalls, etc. In the ulcerative paronychia removal of the nail will often be desirable to prevent its acting as an irritant foreign body.

Syphilitic Onychia is an altered condition of the nails (of both fingers and toes) caused by defective nutrition and not of inflammatory nature. It occurs in the secondary stage of syphilis, both in the acquired and in the congenital forms, and sometimes appears in very young infants. Several nails are usually involved, either simultaneously or successively. It is only exceptionally associated with paronychia. All the forms pursue a very chronic painless course; ultimately recovery is perfect, and normal nails are reproduced.

Syphilitic onychia exhibits a number of different clinical varieties, as follows:

1. In the commonest form, "onyxis craquelé," in mild cases the nail becomes dull and lusterless, yellowish, brittle, and breaks easily on its edge; a similar condition may also occur in other chronic or debilitated conditions. In severe cases the nail in addition becomes marked by parallel ridges, and the free edge thickens and cracks and breaks easily, leaving an irregular broken margin. This condition is sometimes associated with dry paronychia.

2. In a second variety, the nail gradually and insidiously separates from the nail bed, beginning distally and extending toward the root of the nail. The separated portion is discolored. Usually the nail is only partially detached, but occasionally it is entirely cast off.

3. In another form the growth of the nail or formation of the nail substance is entirely or partially arrested. The boundary between the old nail and the new portion is formed by an irregular transverse line, which advances toward the end of the nail. The old nail becomes discolored, ridged, loosened, and finally drops off, and its place is taken by epidermis or by a thin and imperfect nail structure.

4. There is also a hypertrophic form, in which the nail becomes greatly thickened, with its surface dry, uneven, cracked and split, yellowish, dirty, unsightly.

Besides these varieties other forms of syphilitic onychia sometimes occur, similar in their general nature, all being conditions of lowered nutrition. The treatment consists in the administration of salvarsan or mercury (rather than iodide), with tonics, etc., in debilitated conditions. The finger tips should be protected by stalls, etc. The prognosis is good, and well-formed nails are almost always ultimately produced.

Syphilitic Dactylitis is a specific involvement of the tissues of the digits presenting distinctive clinical features, first definitely recognized by R. W. Taylor in 1871. It is one of the tertiary or late manifestations of syphilis, and occurs both in acquired and in inherited forms of the disease, and hence both in chil dren and in adults. The fingers are oftener attacked than the toes. Any of the fingers may be affected, but the middle and ring fingers are said to be oftenest involved. One finger may be affected, or several, simultaneously or successively. The lesion consists essentially in a gummatous infiltration of the soft or hard tissues, which is apt to undergo necrosis and ulceration, together in some cases with chronic inflammation and secondary pyogenic infection. Two varieties of the disease are distinguished: (1) that in which the subcutaneous and ligamentous structures are primarily and chiefly affected, and (2) that in which the bone or periosteum bears the brunt of the disease.

1. In the first variety, or "syphilitic panaris," the subcutaneous fibrous tissues about the joints undergo gummatous infiltration. The dorsal surfaces are rather more liable to this form than the palmar surfaces, and the proximal phalanges are especially affected. The parts affected increase in size and are tense and hard, or soft and semi-fluctuating. The overlying skin is purplish or violet in color. The gummata may break down, but do not tend to suppurate. The course of the affection is very chronic and nearly painless, and it is sometimes very resistant to treatment. and tends to recur. This

condition may be distinguished from gout, acute rheumatic arthritis, or whitlow by its chronic painless course; from chronic arthritis by the location of the initial lesions in the joints, the early deffection of the phalanges, and the non-discoloration of the skin in the latter, as well as by the concomitant symptoms and history. The prognosis is good, and recovery with a useful finger may be ultimately expected, unless the joints are seriously damaged.

2. In the second and more typical form of syphilitic dactylitis the marrow and deep layer of the periosteum are primarily involved. As the result of the syphilitic inflammation the bone is destroyed, and sometimes a new layer of bone is formed at the periphery causing an enlargement of the phalanx or metacarpal.

In typical cases there is marked spherical or fusiform enlargement of the affected phalanx. The soft parts are stretched; the skin is purple, violet, livid or red, shiny or dull. When the gummatous enlargement is advanced the new tissue breaks down into a fluid discharge or cheesy mass; ulceration takes place; secondary infection with the ordinary pyogenic germs may occur, and suppurating sinuses are formed. Extension to the joints may follow. Pain varies, frequently not being marked, but sometimes severe, often worse at night. Usually only one phalanx in a digit is affected, sometimes more. The proximal phalanx is the one most often invaded; not infrequently the metacarpal bone suffers. The course of the disease is chronic, or often subacute.

After recovery the new tissue may entirely disappear, or permanent changes remain. Decrease in size, with alteration in length or thickness, may follow necrosis and destruction of bony substance; increased size may result from formative osteitis. Cicatricial contractions may supervene. Joints may be destroyed, or false joints may be produced (from nonunion after necrosis of bone), constituting a very disabling flail joint. Rarely ankylosis results. The prognosis on the whole is favorable; involvement of a single phalanx without extension to the joint is apt to recover without bad consequences. Loss of substance, the formation of flail joints, ankylosis, or cicatricial contractions may impair appearance and usefulness, and often to a great degree.

The diagnosis of syphilitic dactylitis from tuberculous dactylitis is extremely difficult, often impossible. From ordinary whitlow it may be differentiated by its less painful and more chronic course and development, and the history of the case. From cartilaginous and bony tumors it may be distinguished by its less sharp localization, the tendency to necrosis, ulceration, and suppuration, the history, and the results of specific treatment. From various hypertrophic conditions, the clinical course and features and the inflammatory and ulcerating phenomena of syphilitic dactylitis will enable the diagnosis to be made.

In the treatment of syphilitic dactylitis, salvarsan, mercury and the iodides will be our main resorts. The possibility of the persistence of a discharging sinus, on account of mechanical conditions in the bone, must not be overlooked. A subperiosteal resection of a damaged shaft may be necessary. Too much should not be done locally. Gummata should not be opened or removed, and amputation is contraindicated; but if suppuration sets in it should be treated on ordinary surgical principles, by opening of abscesses and sinuses, removal of necrosed bone, etc.

Other Infections and Parasites.—Infection of wounds with other than the ordinary pyogenic bacteria is liable, from its exposure, to occur in the hand, as in some postmortem wounds, laboratory infections, infection with the gas bacillus, anthrax, glanders, rabies, tetanus, etc. Some of these infections are very malignant and grave, though fortunately uncommon. The morbid condition is manifested either locally or systemically, or in both ways. The local condition consists in an inflammatory process in the tissues adjacent to the wound, with clinical features varying according to the infective agent.

The systemic manifestations are of septicemic, metastatic, or toxemic character, and constitute the element of danger in these cases. In some conditions, as in rabies and tetanus, substantially the entire clinical picture is made up of the constitutional manifestations, with practically no morbid condition at the point of original entry of the infection. Tetanus frequently follows wounds inflicted by the blank cartridges of toy pistols.

The treatment of infected wounds of the hand is the same as that of these wounds generally—efforts at local destruction of the infecting parasites and their toxins, and cure of the local inflammatory lesions, with appropriate measures to combat the general manifestations. All wounds made by blank cartridges should be laid open thoroughly, so that air may have access to them.

Gonorrhea may affect the hand in the form of gonorrheal arthritis of the wrist joint; also occasionally as a gonorrheal thecitis or other inflammatory affection.

Leprosy affects the hands severely, especially in the anesthetic variety. In tubercular leprosy the noduar masses may develop in the fingers and hand, though this member does not usually suffer so severely in this respect as other parts of the body; the nodules about the fingers may break down and ulcerate. In anesthetic leprosy the hand is wont to become exceedingly deformed and mutilated, from disintegration and necrosis of the joints and bones, ulceration of the skin and soft tissues, atrophy of the tissues, and deflections and contractions of the digits. The fingers and even parts of the hand often drop off spontaneously. The parts are anesthetic, and the course of the affection is very slow and chronic. Claw-hand sometimes occurs in leprous neuritis.

Scabies usually makes its first appearance on the hand, whence it is conveyed to other parts of the body. The sides of the fingers and the interdigital angles are the points particularly attacked. The *trichophyton* fungus frequently invades the back of the hand, in the clinical condition known as tinea circinata. At least three cases of *hydatid* or *cysticercus* cysts in the hand are on record: one in the subcutaneous tissues of the palmar surface of a proximal phalanx, one beneath the palmar fascia in the palm, one originating within a proximal phalangeal bone and causing distention of the phalanx to the size of an orange. *Elephantiasis* has been already mentioned.

Cicatricial Contractions.—These often occur about the hands and fingers, with consequences ranging up to extreme deformity and disability, and the usefulness of the hand is at times almost completely destroyed. These contractions may develop after the cicatrization of wounds or ulcers of any sort, as after lupus or syphilitic ulcers, but especially after the healing of ulcers from burns. Protracted granulation favors the development of deforming cicatrices. The deformities produced are very various, consisting of palmar, dorsal, or lateral deflections of the fingers, acquired syndactylism, etc.

The successful treatment of these cases is quite difficult, as there is a strong tendency to recurrence after ordinary plastic procedures. As a prophylactic measure may be mentioned treatment of ulcers likely to be followed by contracting cicatrices in such manner as to shorten the period of granulation and healing, as by attention to asepsis or by skin-grafting. Still, in slow-healing ulcers like those from burns, there is little certainty of escaping contraction.

Even the keeping of the parts in a corrected or over-corrected position by splints or appliances is not very successful.

The ordinary plastic operations sometimes succeed, but often do not secure permanent results. Among such procedures may be mentioned the lifting of a V-shaped flap, exsection of the cicatricial tissue, straightening of the parts, and final suturing of the wound in a Y-form. The Thiersch and Reverdin

Fig. 2953.—Cicatricial Contraction in the Hand. (Gross.)

modes of skin-grafting for filling defects after dissectign out the vicious tissue are not very successful.

The treatment recommended as most successful in these cases is a radical transplantation of a skin flap, one end of which is left with its original attachment and vascular supply intact until the flap is firmly united in its new position. The contracting scar tissues are divided and removed as much as possible, and the deformity is corrected. Into the gap thus

Fig. 2954.—Cicatricial Contraction in Hand. (Erichsen.)

left a flap of proper size, composed of the entire thickness of the skin, is brought and sutured. One end of the flap, affording the best vascular supply, is left unseverd from its original attachment until, after two to four weeks, the flap is well united in its new position. This flap can be taken in any convenient situation from the thorax, abdomen, or back, and the hand and arm bandaged in place until union is complete, when the flap is entirely detached from its

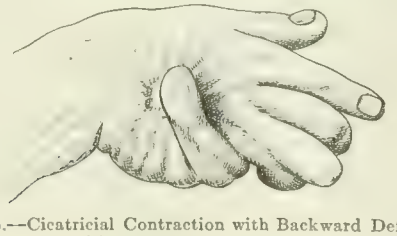

Fig. 2955.—Cicatricial Contraction with Backward Deflection of Little Finger. (Erichsen.)

original situation. In some cases it is probable that a similar flap could be taken from the dorsum of the hand and twisted around in position to fill a defect.

In intractable cases of great deformity amputation may be indicated, though it should be remembered that often a poor finger is more useful than no finger at all.

Effects of Occupation on the Hand.—The effects of an individual's occupation or habitual mode of life and environment may become marked by reactive consequences, structural and functional, upon various parts of the body, and especially upon the hand, since this member is so actively and constantly exposed and employed. The effects produced on the hand by occupation are not only of some clinical importance but are also of anthropological interest and medicolegal significance.

Among the many various factors which produce effects on the hand may be mentioned friction and pressure, as from the use of instruments and tools or the manipulation of machinery, which may have hypertrophic, irritative, or destructive consequences; frequent exposure to chemical substances, with irritant, caustic, emollient, staining, or other action; exposure to physical agencies, heat, cold, weather, sun; deposition of foreign matter; the frequent repetition of slight traumata, "occupation insults," ultimately producing cumulative results Any of the tissues and any part of the hand may be the seat of the alterations produced by occupation, and the changes may be either organic, with definite structural alterations, or functional and without anatomical changes. The particular changes set up vary in their site and nature according to the circumstances. While many vocations do not produce definite effects on the hand, others do produce distinctive and characteristic results.

Only a brief consideration of the general effects produced in the various tissues can be attempted here. For full and detailed information on the subject reference may be made to such works as that of Vernois, already cited.

The epidermis, from its superficial and exposed position, naturally exhibits marked effects from use. From continued pressure or friction it becomes very often hypertrophied, thickened, and hardened, especially on the palm, and either over the whole palmar surface or in circumscribed and distinctive localities (callosities) according to the site of pressure, as on the left finger tips of violinists. A man's occupations often may be told from the callosities on his hands. From exposure to water and other fluids, caustics, alkalies, acids, and similar strong chemicals, the epidermis may be softened, thinned, atrophied, or even entirely destroyed.

The temperature of the hand may be affected by alterations in the development of the superficial vessels, being lowered in those who work with their hands in cold water, or habitually elevated and increased in those who work in hot places (as bakers).

The subcutaneous tissues may be thinned or thickened by the same factors that produce like results on the culticle and cutis. The hands of those engaged in hard manual labor often exhibit a marked general palmar induration. The skin and underlying tissues become generally thickened, hard, rigid, and inelastic, and somewhat contracted so that the fingers are held slightly flexed and their full extensibility is somewhat impaired. From the action of irritants subcutaneous edematous accumulations may be developed. Enlarged bursæ may appear at points exposed to pressure, as on the back of the right wrist in sawyers (Vernois).

The veins of the hand may become dilated from habitual exposure to heat. The muscles may to a certain extent become hypertrophied, atrophied, or shortened, according to their use or disuse. Special muscular activity and mobility and manual dexterity are developed in some occupations, as in pianists and many others. Habitual holding of the hand in certain positions, as with drivers, sometimes results in more or less rigid fixation of the hand or fingers in a flexed or other position—the *occupation* or *habit contracture*. Overuse of groups of muscles sometimes causes them to atrophy—*occupation muscular atrophy*. The nerves do not undergo perceptible anatomical alterations, but various occupations may produce serious functional nervous disorders of the hand, forming the

important clinical class known as "occupation neuroses," typified by writers' cramp.

The articulations may be variously affected by occupation. Sometimes the mobility of the joint is increased, sometimes it is diminished, or there may be complete ankylosis. The finger joints may be enlarged, from exposure to repeated injury, as in baseball players. (See J. N. Hall.[11]) Partial luxations may occur, and deflections of the phalanges may be produced (as a backward deviation or superextensibility of the distal phalanx of the thumb in jewelers). From being kept in habitual special positions, corresponding changes may take place in the articular structures, as pressure atrophies, lengthening or shortening of ligaments, etc. Even the bones may undergo changes, as a spatuliform flattening of the phalanges from pressure.

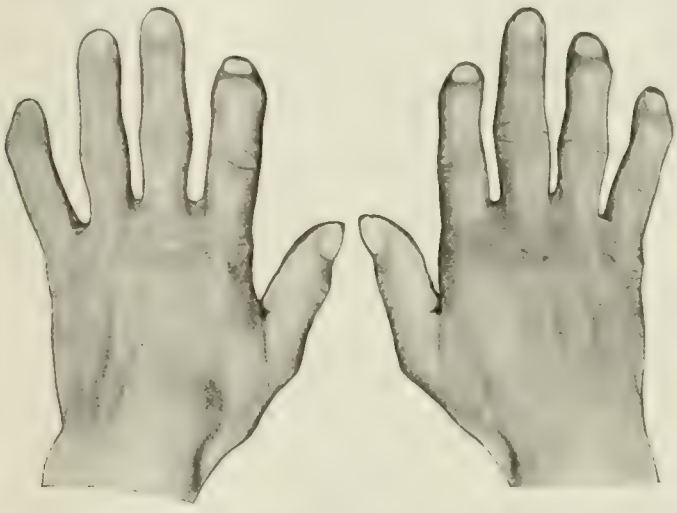

Fig. 2956.—Hands of a Baseball Player, Showing Characteristic Alterations. (Nichols.)

As an example of occupation deformities may be mentioned the effects often produced in the hands of baseball players, which are very characteristic (Fig. 2956). The typical changes in these cases consist in an enlargement of one or more of the distal phalangeal joints, along with slight lateral or palmar deflection of the terminal phalanges, which have a shortened appearance. The flexions may be caused by the rupture of the extensor tendon of the terminal phalanx. In such case, active extension is impossible, but passive extension is unimpeded. Sometimes the affected joints are partially or completely ankylosed, though not always so.

No general rules as to treatment can be laid down, as the lesions and factors are so various in different cases. Change of occupation is obviously a therapeutic measure of general applicability in these cases. Occupation dermatitis and occupation neuroses will be referred to subsequently.

Affections of the Nails.—The lesions of these structures may be divided into inflammatory and necrotic conditions (paronychias), changes in the substance of the nails (nutritive or trophic changes), atrophy, absence, hypertrophy, changes in form, changes in color, and parasitic conditions.

Inflammatory and Necrotic Conditions—Paronychia.—The nail substance from its histological structure cannot itself be the seat of real inflammation. The tissues contiguous to the nail and from which it derives its growth and nutrition (the bed, matrix, and root of the nail) are, however, subject to special forms of inflammation, and to such conditions the terms onychia (or onychitis) and paronychia are variously given. The term onychia is also applied to certain purely nutritive and trophic lesions of the nails. Other affections of these tissues in their clinical features resemble inflammatory paronychias, though primarily rather necrotic in character. The chief varieties of paronychia are the traumatic, infectious, malignant, syphilitic, tuberculous, diabetic, toxic, and trophic forms, besides those forms in which the cutaneous tissues adjacent to the nails are affected with various skin diseases, especially eczema and psoriasis. Of these forms of paronychia, the common acute variety due to infection with pyogenic bacteria and the syphilitic and tuberculous varieties have been already considered.

Traumatic Onychia and Paronychia is that caused by injuries, especially contusions. In cases of great violence the nail may be loosened and immediately cast off. In less severe cases, effusion and transformation of blood may give the nail a black color; in the course of time the nail often becomes slowly and gradually loosened from its bed, in whole or in part, and may be entirely cast off. If infection occurs the case is materially aggravated. The tendency is toward repair and recovery with ultimate reproduction of a perfect nail. The parts should be kept protected, dead nail should be removed, and infection guarded against. The severe pain which often follows the effusion of blood under the nail can be cured by boring a hole through the nail with the point of a clean knife.

Malignant Paronychia (or malignant onychia) is an indolent inflammatory, suppurating, necrotic, or ulcerative affection of the nail matrix and bed, originating in a slight traumatism, and confined usually to a single nail. It affects especially persons of lowered vitality and in unhealthy condition. It begins with simple inflammation, later proceeding to suppuration and ulceration. The nail becomes thickened, opaque, discolored, loosened, and cast off. The course of the disease is slow and indolent, and may become chronic; or the ulcer may slowly heal, and an imperfect nail be formed. The inflammation frequently extends to the subcutaneous tissues or the bone. The treatment consists in local measures to stimulate healing, and in vigorous constitutional and tonic treatment.

Diabetic Paronychia is the form of diabetic gangrene in which the circumungual tissues are the seat of the necrotic process or tendency, shown by sluggish inflammation or ulceration. The treatment is that of the constitutional disease.

Toxic Paronychia, that produced by the action of toxic agents, is well exemplified by the characteristic local lesions—ulcers at the roots of the nails—produced by arsenic in the hands of those who work with this substance. The obvious treatment is discontinuance of the cause.

Trophic Paronychia is the necrotic and inflammatory process about the nails which results from morbid nervous action in various neuroses such as syringomyelia or Morvan's disease, "glossy skin," Raynaud's disease, leprosy. The process is primarily degenerative and necrotic, but the lowered vitality of the tissues predisposes to sluggish infection and inflammation. The destruction of tissue may be extensive, involving even the bone, and the course is apt to be prolonged. The treatment is local and that of the cause.

Nutritive Alterations of the Nails.—While the nail substance proper is scarcely liable to inflammation, it is subject to nutritive and trophic alteration, mostly of a degenerative character, which may be produced by a considerable variety of causes.

The term onychia is applied to some forms of these alterations. The changes of a degenerative, malnutritive, or trophic character which the nails may exhibit are very various, such as loss of luster, changes in color (white spots, etc.), softening, brittleness, friability, fragility, thinning, thickening, longitudinal or transverse furrows and ridges, laminations, exfoliation, splitting, irregularity of surface (elevations and depressions), etc.

These trophic alterations may be grouped into three etiological classes: (*a*) those due to local conditions or causes, as paronychia, dermatoses, trauma; (*b*) those due to constitutional diseases, especially those with a lowering of the general nutrition or vitality, and (*c*) those due to morbid trophic influences of nervous origin.

The paronychias do not all cause impairment of the netrition of the nail, but in some cases, as in malignant paronychia, ulcerative syphilitic paronychia, and trophic or necrotic paronychias, the nail substance is apt to suffer, or may be entirely cast off. Skin diseases affecting the nails or adjacent cutaneous tissues, especially eczema and psoriasis, may cause malnutritive changes in the nails. Similar effects may be produced by trauma, contact with strong chemicals, parasitic affections of the nails, etc.

Severe constitutional diseases in which there is a great drain on the vital powers and the general nutrition is lowered, such as acute fevers, syphilis, scurvy, diabetes, gout, cancer, and others, also senility, may produce trophic changes in the nails. The syphilitic onychias have been already described. After acute diseases the ungual changes appear in the period of convalescence. Transverse furrows or white bands, representing temporary arrest of growth, sometimes appear after typhoid fever and other diseases. In relapsing fever two or three such transverse markings sometimes occur, one following and corresponding to each febrile paroxysm. Longitudinal ridges—"reedy nail"—occur in gout, senility, and other conditions.

In the third class of cases nutritive changes in the nails are produced by morbid, trophic, nervous influences arising from various nervous disorders, as in association with neuritis—multiple neuritis, gouty neuritis, leprosy, "glossy skin"—or with central nervous diseases.

In the treatment of these conditions the nails should be kept trimmed and in good order, protected by a coating of wax, and guarded against injury. The local or general condition giving rise to the ungual lesions should receive the appropriate treatment.

Atrophy of the Nail can scarcely be distinguished from certain forms of nutritive alterations, and is similar in its etiology and pathology to the latter.

Absence of the Nails (*Anonychia*) may be congenital or acquired. Rarely the nails are entirely absent from birth, either without any other developmental anomaly or in association with developmental defects like hypophalangism. The nail may be totally and permanently abolished by traumata or diseases causing complete destruction of the nail-forming tissues.

Hypertrophy of the Nail (*Onychauxis*) may consist in an increase in thickness, or in a lateral expansion (ingrowing nail). Both conditions are much commoner in the toes than in the fingers. In many cases enlargement of the nail is a result of nutritive abnormality, the increased nail substance being discolored, friable, brittle, fragile, etc. Hypertrophy of the finger nails occurs in connection with congenital dactylomegaly, traumata, occupation effects, lack of cleanness, syphilis (hypertrophic syphilitic onychia), fungous growths, chronic skin troubles in the vicinity like eczema and psoriasis, nutritive and neurotrophic influences. The treatment is that of the cause.

Changes in Form of the Nails may result from traumata, occupation effects, nutritive or circulatory disturbances, or local disease. An increased transverse curvature is said to be produced by syphilis, hemiplegia, and free perspiration. An increased longitudinal curvature occurs in Hippocratic fingers and hypertrophic pulmonary osteoarthropathy. "Spoon nail" is a condition in which the nail is concave transversely, with everted edges; it has been observed in connection with wasting diseases. Changes in relative length and breadth of the nails may also occur, as in rickets, in which the nail is said to be relatively shortened.

Changes in Color of the Nails may arise from staining by extrinsic substances or from intrinsic pathological processes.

The commonest change of color is to white, in the form of white spots, white bands, or whiteness of the entire nail. *White spots* on the nail ("flores unguium") are very common in children, usually occurring without perceptible cause; they may also be produced by injuries, trophic alterations, and constitutional diseases. Their pathology is not well understood. They are attributed to the presence of air in the nail substance. *Transverse white bands* sometimes appear after febrile attacks, sometimes occur in persons in good health, sometimes are congenital. *Complete whitening* of the nail occurs rarely, as after severe fevers or in paralytics.

Black Discolorations of the nails are common, from extravasation and transformation of blood pigment after contusions. Small black spots rarely appear on the nails after severe illness.

Parasitic Affections of the Nails.—The nails may be invaded by various parasites, either fungous (onychomycosis) or animal. The commonest form of onychomycosis is that produced by the trichophyton fungus; this, however, is infrequent, and usually secondary to or associated with tinea trichophytina elsewhere. Rarely the nails are affected by favus. Nails invaded by fungous growth are thickened, soft, brittle, lusterless, grayish or yellowish-white, and in a defective nutritive condition. The appearance is similar to that of nails suffering malnutritive or trophic alterations, so that the diagnosis is with most certainty made by microscopical examination.

The treatment of nails infected with parasites consists in removal of the nail by scraping or applications of caustic alkali, with parasiticide applications (creosote, acetic acid, mercury bichloride, sulphur, etc.).

Affections of the Skin.—The skin of the hand is in general subject to disease in a similar manner to the rest of the body; but special or peculiar features are exhibited in many of the dermatoses of this locality, caused by exposure of the hand to atmospheric and meteorological conditions, to acute or chronic irritant influences of mechanical or chemical nature, and other factors.

Some dermatoses affect the hands indifferently or similarly or along with other parts of the body, without any peculiar features or special susceptibility or insusceptibility, as pemphigus, dermatitis herpetiformis, lichen ruber, ichthyosis, impetigo herpetiformis, prurigo, herpes zoster, molluscum contagiosum, scleroderma, mycosis fungoides, cornu cutaneum, and many others. To some dermatoses the hand is not at all subject, as seborrhea, tinea versicolor; or less subject than other localities, as corns, psoriasis. To some dermatoses the hand is especially prone, and more susceptible than are many other parts of the body, though without manifesting any specially distinctive features, as erythema multiforme, herpes iris, pellagra, frambesia, impetigo, impetigo contagiosa, callosity, warts, glossy skin, pompholyx, tinea circinata, scabies, occupation dermatoses. Some skin affections may exhibit peculiar features about the hand, as some forms of eczema and syphil-

ides. Some dermatoses are peculiar to the hand, or to the hand and foot, as keratosis palmaris, affections of the nails.

In many instances there is a marked difference in the liability of the palmar and dorsal surfaces of the hand to skin disease. Thus, the absence of hairs and sebaceous glands in the palm renders this area insusceptible to diseases of these structures, as acne. The dorsum of the hand is more prone to tuberculous dermatoses, erythema multiforme, keratosis senilis, tinea circinata; while the palm is more subject to most syphilides.

Eczema in its different varieties, acute and chronic, often occurs upon the hands, the liability of which to this dermatosis is increased by the exposure of these members to meteorological influences and to chemical irritants (especially alkalies). The chapping of hands is a form of eczema, induced by exposure to irritating influences. Onychias may result from eczema of the nails or their vicinity. On the palms eczema exhibits special features. Eczema about the hands is apt to be protracted and chronic, and very resistant to treatment. *Psoriasis* may occur both on the palms and backs of the hand, but is less common in this locality than in other situations. Occurring in or about the nails, it may cause an onychia. The backs of the hands are among the commonest seats of *erythema multiforme* and *herpes iris*. The hands are also favorite seats of *impetigo* and *impetigo contagiosa*. The hand may be affected with *dermatitis herpetiformis, pemphigus, herpes zoster, lichen ruber, ichthyosis*, and many other skin diseases in a manner similar to or along with other parts of the body. *Tinea circinata* is common on the back of the hands. *Favus* is much more rare in this situation; sometimes the nails become involved from scratching an infected scalp. The hand is the favorite seat of *scabies*. *Ainhum* sometimes occurs here and causes constriction and amputation of the fingers and even of the forearm. *Pompholyx* (or *dysidrosis*) is a rare vesicular affection, running on to masceration and exfoliation of the epidermis, that involves chiefly the palms and soles, though it may extend to or occur in other localities. *Callosities* are very common about the palm, resulting from habitual pressure or friction; manual labor also causes a general hardening of the palmar epidermis. *Corns* occasionally occur on the hand. *Keratosis palmaris* is a rare condition in which the epithelium of the palm becomes converted into a horny plate. *Glossy skin* is a trophic affection of the skin, due to nerve lesions or injuries generally, affecting especially the fingers; the skin undergoes malnutritive changes, or even actual necrosis, with onychia and pain. *Scleroderma* is a rare condition of sclerosis and contraction of the skin by which the hand as well as other parts of the body may be affected; in the hand it may produce great deformity and disability, the fingers being partly flexed, rigid, immovable, sometimes twisted, and in the later stages with atrophic changes. Tuberculous and syphilitic dermatoses, warts, and affections of the nails have been already considered.

Dermatitis of various kinds is common on the hands, due to their exposure to irritating conditions. Dermatitis traumatica results from traumatic irritation, dermatitis calorica from exposure to the rays of the sun or to other sources of heat and cold, burns, frost bites. In dermatitis medicamentosa lesions sometimes appear on the hands (as from the internal use of copaiba and chloral). The hands are very subject to dermatitis venenata, resulting from direct contact (either accidentally, temporarily, or habitually) with irritating or toxic substances, as in rhus dermatitis.

Allied to dermatitis traumatica, calorica, and venenata is a group of conditions which may be collectively designated *occupation dermatoses*, or *occupation dermatitis*, to which the hand is very subject from repeated and habitual exposure to a variety of pathogenic influences incident to the occupation pursued. The changes in the epidermis, corium, and subcutaneous layer produced by occupation traumatism have been detailed above. In some occupations acute dermatitis may be set up from time to time. Thus, surgeons are sometimes subject to an acute inflammatory condition of the skin of the hands and forearms from hard scrubbing and prolonged exposure to liquids and to irritant chemicals like soft soap, mercuric bichloride, and oxalic acid.

For detailed information as to the clinical features and treatment of the various dermatoses of the hand reference should be made to works on dermatology.

Affections of the Joints.—*Spontaneous subluxations* of the wrist or finger joints may occur in consequence of deforming or destructive joint lesions, as in chronic arthritis.

There is a special class of cases in which a *spontaneous anterior subluxation of the wrist* gradually develops in adolescents engaged in hard manual labor. In this condition there is a partial forward dislocation of the carpus, with an undue prominence of the lower ends of the radius and ulna posteriorly, a diminished range of extension, an increased range of flexion, and a prominence of the flexor tendons. The ligaments are lax and the bones soft. Pain is usually present, at least until full growth is attained. This condition develops from about the age of fifteen to twenty-five years, in persons (especially females) engaged in hard manual work while the bones and joint structures are still soft, weak, and undeveloped. The superior strength and excessive action of the flexor muscles is supposed to be the determining cause of the anterior displacement. The deformity is difficult to overcome. The treatment consists in the use of corrective apparatus, stimulation of the strength and nutrition of the extensor muscles by massage, electricity, and exercise, the use of spring apparatus to reinforce and aid the action of the extensors, and suspension of excessive use of the flexors.

A peculiar affection, characterized by pain over the lower end of the external aspect of the radius, may be due as Goldthwait suggests, to a subluxation of the first metacarpal. It seems to be especially frequent among washerwomen. Goldthwait treats it by a wristlet to hold the bone in place.

A backward dislocation of the terminal phalanx occurs especially in baseball players (described by R. Abbe), in which the end of the middle phalanx is tightly caught between the flexor tendons and through an opening in the anterior ligament, rendering reduction difficult and often necessitating incision upon the joint in order to correct the displacement.

Punctured wounds of the metacarpophalangeal joints, made by the adversary's tooth in fistic encounters are often followed by dangerous sepsis. The custom of practising amputation of the finger at the first sign of infection is a wise one.

Ankylosis may also be a sequela of inflammatory, infectious, or necrotic conditions. Congenital ankylosis of the small joints of the hand and fingers occurs rarely, sometimes being a hereditary abnormity of development. In a considerable proportion of cases of ossifying myositis a developmental ankylosis of the carpometacarpal, metacarpophalangeal, or interphalangeal articulation of the thumb is present.

There is little chance of completely restoring the mobility of an ankylosed finger joint, though arthrectomy or breaking up of the adhesions and bands may be attempted. If the joint is ankylosed at an inconvenient angle an improvement in the position can at least be obtained by operation.

Arthrogenous Deflections of the hand or fingers may arise from a variety of causes, as altered configuration

of the joint structures (as in chronic arthritis), ankylosis in malposition, adhesions and contractions of the developmental abnormities, dislocations, etc. The clinical features and treatment of these conditions vary with the cause. Hammer finger, due to shortness of the lateral ligaments, is an arthrogenous deflection that will be considered subsequently.

Enlargement of the joints of the hand is very common, and while (unless associated with partial or complete ankylosis) it usually causes little or no disability or impairment of function, it is unsightly. It arises from very diverse causes. Enlarged joints are very frequently produced by injuries (see Fig. 2489), and sometimes only slight injuries are sufficient to cause considerable deformity of this kind. The finger joints are often enlarged in persons engaged in manual labor. (See an interesting article by Arbuthnot-Lane.[12]) Deposits or hyperplastic processes about the joints, as in gout and chronic arthritis are a common cause of enlarged joints. Another cause is found in neurotrophic influences, as in Charcot's arthropathy of locomotor ataxia and syringomyelia. Systemic conditions may also be etiological factors; thus, the proximal phalangeal joints are said to be enlarged in cases of dilated stomach. Enlarged joints of the hand should be treated according to their cause.

Synovitis and Arthritis.—The inflammatory affections of the joints of the hand are chiefly of traumatic, infectious, tuberculous, syphilitic, or gonorrheal nature. In addition to these are the rheumatoid arthroses, chronic arthritis, gout, characterized by abnormal trophic processes or deposition of abnormal material.

Gout.—Next to certain joints of the foot, the joints of the fingers are the most common seats of gouty lesions. These consist of deposits of urates, at first in the articular cartilages, then in the synovial and fibrous structures of the joint, then in the tissues surrounding the joint. These deposits, when in

Fig. 2957.—Gouty Hand. (Meillet and Richer.)

sufficient amount, constitute "tophi" or "chalk stones," and produce characteristic nodular enlargements about the affected finger joints. The mobility of the joints may be impaired. At times the tophi may ulcerate out, or may cause damage to the articulation itself. Urates may be also deposited in the cutaneous or subcutaneous tissues of the palm, or in the tendinous structures. The treatment is that of gout in general.

Chronic Arthritis.—The joints of the wrist and hand are vulnerable to the same infections as are those of the rest of the body; and the reader is referred to the section on Arthritis for a full description of the subject. Manifestations of both the proliferative and degenerative forms (Type I and Type II) are very frequent in the fingers. In a general way the multiartricular, progressive division of Type I affects the proximal interphalangeal and the metacarpophalangeal joints, and causes flexion deformities. Type II manifests itself as lateral or flexion deformities in the terminal interphalangeal joints.—Heberden's nodes. The former are almost certainly due to some infection located somewhere else in the body, *e.g.* tonsil, genito-urinary apparatus, and are best treated by the removal of the infection. The latter are not of great importance, except for their unsightly appearance. They are, in fact, viewed by some as an evidence of longevity.[13]

Ulnar Deflection of the Fingers at the metacarpophalangeal joints is common in elderly persons, as if it were a senile change. It may also appear in earlier adult life as a consequence of acute or subacute arthritis of the metacarpophalangeal joints. This condition, although but a slight deformity, presents a characteristic appearance; the little, ring, middle, and index

Fig. 2958.—Arthritis Deformans. (Meillet and Richer.)

fingers are slightly flexed, and bent laterally to the ulnar side at the metacarpophalangeal joints.

Changes in Extensibility of Metacarpophalangeal Joint of the Thumb at Different Ages.—In many cases the structures making up the metacarpophalangeal articulation of the thumb undergo progressive changes at different periods of life, such that while in childhood the proximal phalanx of the thumb is markedly lax and superextensible, in old age its extensibility may be diminished very much below the norm of the adult period. The condition of this joint is therefore to be considered in three periods—in childhood, in the adult, and in old age.

1. In young *childhood* in a large proportion of individuals the ligaments of the joint in question are very lax, so that the proximal phalanx can be super-

Fig. 2959.—Chronic Multiarticular Inflammation—Type I, Radial Deflection of Fingers and Superextension of Middle Phalanges.

extended or bent backward at a marked angle, even to a right angle (see Fig. 2960). Usually the superextension can be accomplished by the free and unassisted action of the extensor muscles; occasionally the superextension can be brought about only by assistance or passive action. The position of superextension is a sort of subluxation of the joint, and the phalanx when extended goes back with a sudden slip. The condition is by the laity often called "double-jointedness." This laxity of the joint is very common in children up to the age of six or seven years, occurring to a greater or less degree in nearly a half of white children. After that age the superextensibility gradually diminishes, until about the age of puberty, when it usually has entirely disappeared. Occasion-

ally, however, superextensibility of the thumb persists to maturity, especially in persons whose finger joints generally are unusually lax, and in those in whom this laxity is developed and maintained by such occupations as piano playing.

The superextensibility varies in extent from a slight increase to an extreme degree of laxity. Usually both thumbs are superextensible, though sometimes one thumb, especially the left, may be affected alone. The left thumb appears to be rather more subject to this peculiarity than the right, as shown by its being often superextensible to a greater degree

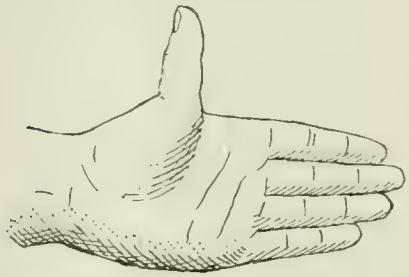

Fig. 2960.—Hand of a Boy Six Years Old, Showing Voluntary Superextension of Thumb. (Original.) Nichols.

than the right when both thumbs are involved, and by its being most subject when only one thumb is affected. The two sexes are about equally subject to this condition.

Among seventy-three colored children, thirty-eight girls and thirty-five boys, aged from two to fifteen years, superextensibility of the proximal phalanx of the thumb was noted in only two instances (girls, aged ten), and that to a slight degree only. This would indicate that the peculiarity is less common in the negro race.

Fig. 2961.—Hand of a Man Aged Thirty-three, Showing Full Normal Adult Extension of Thumb. (Nichols.)

2. In the *adult* period the first phalanx of the thumb when fully extended normally lies in line with the metacarpal bone, or at an angle slightly short of this line (Fig. 2961).

3. In *old age* not infrequently the proximal phalanx of the thumb is very much decreased in extensibility, so that when fully extended it cannot be brought within a considerable angle (often not within forty-five degrees) of the line of the metacarpal bone extended (Fig. 2962). With this, the distal phalanx is often considerably superextended and curved backward. The condition occurs alike in those who have or have not been subject to arthritis and in those who have or have not pursued laborious manual occupations.

The superextensibility of the thumb in childhood appears to be due to laxity of the ligamentous structures of the metacarpophalangeal joint. Its subextensibility in old age appears to result from shortening of the ligaments or alterations in the configuration of the hard parts of the joint, produced either by senile changes or perhaps by a mild and distinctive form of arthritis deformans.

Fig. 2962.—Hand of a Man Aged Sixty-nine, Showing Full Extension (Much Diminished) of Proximal Phalanx of Thumb. This subject had been a clerk by occupation, doing no manual labor, and had not had arthritis. (Nichols.)

Senile Joint Changes.—The finger joints in old age often exhibit alterations. The finger joints often have a diminished range of mobility. They sometimes have an enlarged appearance, partly from real enlargement, partly from atrophy of the soft tissues of the phalanges. Ulnar deflection of the fingers is frequently seen, without other material evidences of rheumatoid arthropathy. Beitzke[14] in a series of consecutive autopsies found regularly degenerative changes in the joint of subjects over forty years of age.

Affections of the Tendons and Tendon Sheaths.—Small fibromatous *tumors* occasionally develop on tendons, especially on those of the flexor muscles of the fingers, palpable as subcutaneous nodules moving with the tendons and not causing material trouble unless they interfere with the action of the tendon or become painful from pressure. Some forms of trigger finger are produced by the impediment to motion caused by such tendinous nodules.

Tenosynovitis.—One of the favorite seats of various forms of inflammation of the tendon sheaths is about the wrist, hand, and forearm. Infectious and suppurative inflammation is common in connection with whitlows and palmar abscess; pain is intense, early and free incision is necessary, and the consequences may be serious. Gonorrheal tenosynovitis sometimes occurs about the hand, and syphilitic involvement of these structures may occur.

Acute non-suppurative tenosynovitis may occur in the hand or forearm, from occupation irritation, contusions or other traumatisms, or spontaneously from undeterminable causes. The symptoms are pain, swelling, friction and crepitation, effusion of fluid.

The treatment consists chiefly of rest and immobilization. Tight strapping with adhesive plaster forms an excellent routine treatment.

Chronic Tenosynovitis in all or nearly all cases is of tuberculous nature. Most of the cases occur in the

forearm and hand. It presents a number of forms—a simple serous effusion into the thecal sac, an effusion with rice grain bodies, or an exuberant granulating form. It occurs more especially in women, in the delicate and unhealthy, and in those with a family or personal tuberculous taint; manual work, like wringing clothes, sometimes predisposes to it. The onset is gradual and the course very chronic. Pain is not severe.

In the forms with effusion there is an elongated swelling along the course of the tendon, with fluctuation. The inflammation may be confined to a limited portion of the tendon, or may extend the entire length of the sheath and to other sheaths.

In the fungous granulating forms the tendon and sheath are involved in an exuberant granulation process, which causes irregular distention along the sheaths, with a peculiar feeling, but no fluctuation.

The site of tuberculous tenosynovitis is especially on the dorsal or palmar aspect of the wrist, though it may extend along the anterior or posterior surfaces of the digits. At the wrist, the annular ligaments passing over the tendon sheaths may cause a constriction in the swelling at that point, forming an

Fig. 2963.—Superextension Resulting from Non-union of Flexor Tendons of Middle, Ring, and Little Fingers, Severed by an Incised Wound Twenty-six Years Previously. (Nichols.)

hour-glass appearance, sometimes called "compound ganglion." Chronic syphilitic tenosynovitis is rare, but probably does occur. It cannot be distinguished clinically from tuberculosis. I have one specimen which was dissected out with a diagnosis of tuberculosis, but whose microscopical examination failed to show any tubercles. A course of antisyphilitic treatment is advisable when any doubt exists as to the diagnosis.

Ganglion.[15]—A ganglion is a small, tense, obscurely fluctuating cyst-like structure, usually ovoid in shape, whose contents consist of a clear, viscid, mucilaginous, mucoid or colloid material. The wall is composed of fibrous tissue. Certain writers have described the lining of the capsule as endothelium, but this is probably an error. A synovial lining is not present. The ganglion may be divided off into several compartments by septa, complete or incomplete. The wall may contain other "daughter" ganglions. The favorite sites are the radial side of the dorsal aspect of the wrist, among the extensor tendons, the palmar aspect of the fingers beneath the flexor tendons, and the radial side of the palmar aspect of the wrist beneath the radial artery. Ganglions of the dorsal, the most frequent, aspect of the wrist are usually attached to the capsular liagment or to a tendon sheath or to both, but the cavity of the ganglion does not communicate with that of the joint or tendon sheath. Any apparent communication is almost invariably due to carelessness of dissection at operation.

The pathogenesis of ganglion has attracted much attention, but the problem remains to be solved. Three theories have been advanced. (1) A ganglion is a hernial protrusion from a joint or tendon sheath. This is unlikely. (2) A ganglion is an adventitious bursa whose contents have undergone a colloid or mucoid change. (3) A ganglion is the result of a cystic degeneration of connective tissues. The third hypothesis is by far the most probable.

The essential cause is unknown. The element of strain seems to be a strong one—an assumption based on the frequency of ganglion in persons who use their hands vigorously, such as piano players.

A ganglion may appear suddenly or it may be slow of formation. Occasionally it is somewhat painful, but more often not. It is tense, rather hard, and fluctuates obscurely. As a rule it is slightly movable. Its strictly circumscribed nature differentiates it from ordinary inflammations of tendon sheaths, its situation from ordinary cysts.

Treatment.—A sharp blow with a book will often scatter the contents of a ganglion on the wrist, and firm pressure thereafter by adhesive straps should be applied for some time with the idea of preventing its recurrence. The procedure may be repeated if the ganglion return. The most thorough means of treatment is careful dissection of the growth. General anesthesia is advisable. The task is always more formidable than it seems. The ganglion must be followed down to its source, even when the dissection goes down to the underlying joint capsule.

Injuries.—In incised wounds about the wrist, hand, and fingers, the tendons are frequently divided, partially or completely. When the section is complete corresponding impairment of function results, and if the tendon is not reunited permanent damage will ensue. In non-union of divided tendons, the action of the muscles involved is abolished, while unrestrained action of the opposing muscles causes a habitual or excessive deflection, in the opposite direction, of the bony parts supplied. Thus, section of the extensor tendons causes flexion and inextensibility of the phalanges, while division of the flexor tendons results in inflexibility, extension, or even superextension of the phalanges (Fig. 2963).

The consequences, as to the usefulness and appearance of the hand, of non-union of severed tendons are so serious that in all wounds of this region paricular care should be taken to determine if any tendons are divided; and if so, the ends should be sutured together with catgut and the parts afterward kept at rest until union is obtained. If the case be not seen until some time after the injury, the proximal end of the tendon will have been pulled away from the distal, and an operative elongation of the tendon will be necessary.

Subcutaneous rupture of the extensor tendons inserted into the distal phalanges sometimes occurs, giving rise to the condition known as mallet finger.

Adhesions of digital tendons to their sheaths or surrounding tissues are not uncommon from tenosynovitis, especially from whitlow or palmar abscess, or from cicatricial involvement after healing of wounds. Adherent tendons cause a corresponding loss of mobility of the parts supplied by them, or even a greater or less immobility in normal or abnormal positions—the so-called "tendinous ankylosis." In conditions in which adhesions of the tendons threaten attempts should be made to prevent such a consequence. After thecal inflammations and wounds similar exercise of the fingers may prevent adhesions.

After firm adhesions are once established it is difficult or impossible to free the tendons, though a faulty position of a finger might be improved by operative measures.

Mallet or Drop Finger is a condition in which the essential lesion is a subcutaneous rupture of the extensor tendon inserted into the distal phalanx of a finger. It is caused by violence, often slight and insignificant, such as catching the finger tip in the clothing, or a slight push in the direction of flexion on the end of the finger. The tendon is torn at or near its insertion into the base of the terminal phalanx. The rupture may be complete; or it may be partial, a thinning or fraying and stretching of the tendon. In consequence of the rupture the power of extension

(except passively) of the distal phalanx is lost, and from unopposed action of the flexor the phalanx drops limply forward and stands flexed at an angle (up to a right angle) with the finger.

Immediately after the injury there may be some inflammatory symptoms; but as these subside the phalanx is left helpless and inextensible in a flexed position.

The condition is said to be sometimes curable by keeping the phalanx well extended by splints for three or four weeks. If this fails operation is necessary. A longitudinal incision is made over the back of the joint and the ruptured extensor tendon exposed; the

Fig. 2964.—Mallet Finger. (Abbe.)

severed ends of the tendon are then to be sewed together, shortening them if necessary; or the proximal end may be advanced and sutured into the periosteum or into the skin near the root of the nail. After the latter procedure the nail is sometimes temporarily lost.

Affections of Connective-tissue Structures.—Aside from inflammatory and infectious processes in these tissues, the fascial and ligamentous structures of the hand are subject to certain characteristic affections, namely, Dupuytren's contraction of the palmar fascia, contraction of digital fascia, hammer finger, and general palmar induration.

Dupuytren's Contraction.—This not uncommon affection consists in an hypertrophy of definite tracts of the palmar fascia with shortening of the hypertrophied band resulting in flexions or contractions of the phalanges and changes in the configuration of the palm.

While not previously entirely unknown, the true nature of this condition was first demonstrated by G. Dupuytren.[16]. Numerous studies of the disease have since been made and many hundred cases have been recorded. Its morbid anatomy and mechanism have been settled by numerous operations and postmortem dissections, but its etiology is still obscure.

The primary seat of this affection is in the palmar fascia or aponeurosis, a knowledge of the anatomy of which is essential to an adequate understanding of the pathology and mechanism of Dupuytren's contraction. The palmar fascia is a triangular or fan-shaped expansion of firm fibrous tissue radiating over the metacarpus, with the apex of the triangle situated at the depression between the thenar and hypothenar eminences (the "interthenar depression"), where the fascia is contifuous with the annular ligament of the wrist and the tendon of the palmaris longus muscle Opposite the metacarpophalangeal articulations there is a well-marked transverse fibrous band, the "superficial transverse ligament of the palm." At this point many of the longitudinal fibers in the fan-shaped palmar fascia terminate, leaving a few fibers to pass to each of the digits, where they are attached to the skin and fibrous investments of the phalanges. At the web of the fingers there is another transverse fibrous band, the "fibers of Gerdy," or the "superficial transverse ligament of the fingers." The palmar fascia is situated immediately beneath the skin of the palm from which it is separated only by thin masses of fatty and areolar tissue. The fascia is intimately connected with the skin by numerous fibrous bands—a point to be borne in mind in connection with the mechanism of Dupuytren's contraction. Microscopically, the fascia consists of coarse longitudinal and transverse bundles of dense white fibrous tissue, which in places are connected with the corium by smaller fibrous bands crossing through the fatty layer which separates the fascia from the cutis. Among the fibers elongated connective-tissue cells are numerous and minute blood-vessels penetrate and accompany the fibrous fasciculi (see Fig. 2965).

Dupuytren's contraction consists essentially of an hypertrophy or hyperplasia of limited longitudinal portions or fasciculi of the fascia of the palm and fingers together with, usually, contraction or shortening of the hypertrophied band in a longitudinal direction. This condition results in (1) flexions or contractions of the phalanges of the fingers caused by the traction of the shortened bands; and (2) induration and changes in the surface configuration of the palm, caused mostly by traction on the small fibers connecting the band with the overlying corium, or by the thickened and elevated tissues beneath lifting up the skin. Whether the lesion is a hypertrophy or a neoplasm has been a point of discussion. The flexor tendons, which lie beneath the palmar fascia, are not in the least affected, though the bending of the fingers strongly suggests a muscular or tendinous pull. Prolonged malposition and immobilization of the joint in some cases produce changes in the affected articulations; involvement of the tendon sheaths has also been reported.

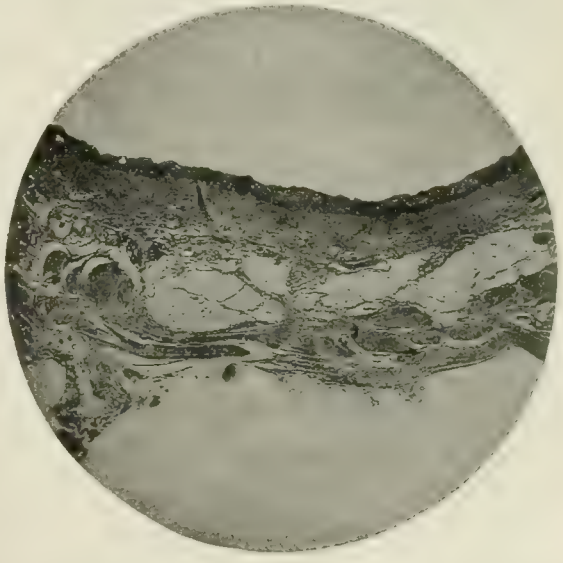

Fig. 2965.—Transverse Section of Normal Skin and Subcutaneous Tissues and Fascia from Right Palm, over Metacarpophalangeal Joint of Ring Finger, from Man Aged Seventy-eight Years, Showing Longitudinal and Transverse Bands of Fascia and Fibers Connecting them with the Cutis. Magnified 10 diameters. (Nichols.)

A few microscopical examinations of the lesion have been made, which afford some information as to its histology. The band causing the contraction, plainly visible to the naked eye, is a prominent rounded or oval longitudinal band of dense fibrous tissue, two to five millimeters in diameter, belonging to the palmar fascia and situated in the subcutaneous tissue. The band may lie in contact with the cutis vera with nothing intervening, though the tissues of the corium and the band are usually distinctly marked off from each other without merging; or the band in places may be separated from the corium by an interval occupied by areolar and adipose tissue.

Microscopically (Fig. 2966) the contracted band is seen to consist of a dense aggregation of longitudinal fasciculi of white fibers, among which are elongated fusiform connective-tissue cells and small vascular channels in greater or less abundance. The tissue is essentially identical with that of the normal palmar fascia, being a hypertrophic or hyperplastic development of the latter. The skin in some instances is rather thickened and indurated, but aside from this all the other elements of the skin and adjacent structures are unaffected.

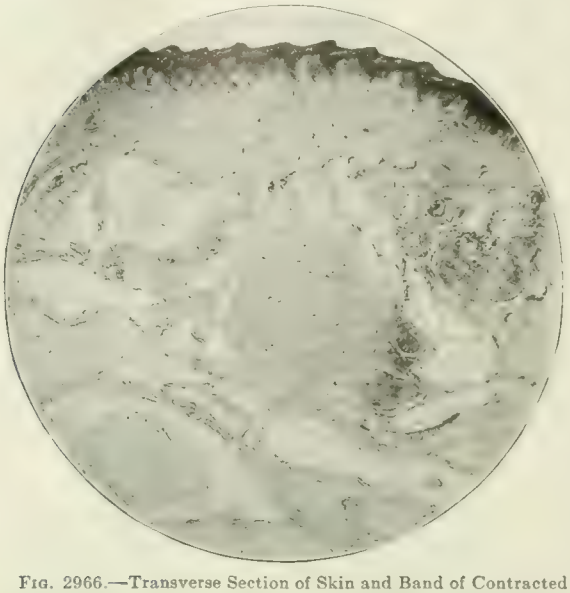

Fig. 2966.—Transverse Section of Skin and Band of Contracted Fascia Leading to Little Finger, Right Palm. Magnified 10 diameters. (Nichols.)

In the early and developing period of Dupuytren's contraction the cellular and vascular elements are exceedingly abundant among the fibrous fasciculi of the contracted band. In this stage there may especially be observable a great accumulation of young connective-tissue cells, small, round, or spindle cells, in the adventitia of, or the tissues immediately surrounding, the small blood-vessels, which are also relatively numerous. Some young fasciculi are composed almost entirely of connective-tissue cells or fibroblasts. As the condition becomes of longer standing and in a stationary stage the vessels and connective-tissue cells decrease in relative abundance, and in old and long-established cases cells and vessels may be in very small number or altogether absent, leaving the fibrous band a dense sclerotic mass.

The condition seems to begin, then, as a rather active proliferation of connective-tissue cells about the small blood-vessels, which themselves become somewhat increased in number. The cells thus proliferating become fibroblasts and develop the fibrous fasciculi which constitute the contracted band. The process is therefore a fibrosis limited to circumscribed longitudinal tracts of the palmar fascia, and is quite identical with the cirrhoses of the viscera or with the process often styled chronic interstitial inflammation. It is practically a hyperplasia or hypertrophy of longitudinal tracts of the palmar fascia together with, usually, a longitudinal contraction of the affected tissue, the thickening being manifested in the transverse diameters.

Cases of Dupuytren's contraction may be in general divided into two clinical groups: 1. The ordinary typical cases in which there is contraction of one or more fingers together with the characteristic manifestations in the palm of the hand. The flexion of the fingers varies from marked deformity and disability to only slight limitation to the extensibility of the digit. This class, therefore, merges gradually into the next group without sharp dividing lines. 2. Cases in which the lesion is confined to the palm with hypertrophy of the palmar fascia and the characteristic thickening, induration, and altered conformation of the surface in the palm, but without contraction of the fingers. These cases are usually slight, yet they sometimes amount to considerable deformity.

The clinical picture is very characteristic. The hypertrophied bands occupy certain definite positions. Running from the direction of the interthenar depression, they cross the concavity of the palm longitudinally, in taut straight lines, as a bowstring is stretched across the concavity of the bow. The thickened and elevated bands form prominent ridges across the palm, very apparent to sight and feeling. The bands pass in direct and definite lines to the fingers, having a definite locus and relation with the metacarpal bones, and do not take the direction of the interspaces between the digits. In the fingers the band usually follows the mid-palmar line; but occasionally, especially in the little finger, the band crosses the proximal phalanx obliquely, or lies toward one side. Ordinarily the bands in the palm do not branch, but each finger has its band distinct

Fig. 2967.—Dissection of Dupuytren's Contraction of Middle and Ring Fingers, from a Specimen in St. Bartholomew's Hospital Museum. *a*, Contracted band of palmar fascia; *b*, flexor tendons; *c*, sheath of flexor tendons; *d*, insertion of contracted bands into base of middle phalanx. (Adams.)

from the others; sometimes a band going to one finger divides near the metacarpophalangeal joint and sends a branch to an adjacent finger.

Besides the ridges formed by the elevated and thickened fascia bands, there are other characteristic alterations of the configuration of the surface of the palm (see Fig. 2968). Minute punctate depressions of the skin, pointing inward and often wristward, are common; they are caused by traction on bands connected with the cutis. Nodules like callosities, formed by indurations of the skin and fascia, are of frequent occurrence. The metacarpophalangeal articulations (especially of the ring finger) are favorite localities for these indurations and inversions of the skin, though they may occur anywhere over the

proximal phalanges. The transverse line in the palm over the metacarpophalangeal articulations is often much deepened by the flexion of the fingers. The traction sometimes produces tension or stretching of the skin.

The mode of distal termination of the bands varies somewhat. Many small fibers terminate in and are connected with the cutis, causing the characteristic depressions of the skin. In many of the cases in which the lesion is confined to the palm the bands terminate near the metacarpophalangeal joints, expending their force on the skin and subcutaneous tissues at those points instead of drawing on the fingers. Occasionally a thick and well-marked band proceeds some distance up a finger, yet (not being shortened) without producing any flexion of the phalanges. Many bands terminate by a general blending with the skin or subcutaneous fibrous investments of the finger, usually around the proximal phalanx; many others have a more or less distinct insertion, especially at the proximal end of the middle phalanx.

The contraction of the fingers is caused by the traction exerted by the shortened palmar bands, and consists in a limitation of the extensibility of the finger; within the limits allowed by the contracting band flexion and extension are unimpeded, but beyond them further extension is impossible. The degree of contraction varies from complete flexion of the finger into and against the palm to only slight limitation of the full extensibility of the finger. The contracting force may be exerted on any of the three phalanges, though almost always on the proximal or middle and only very infrequently on the distal phalanx. When the traction is exerted on the proximal phalanx, mostly by a general pull on the skin and fibrous investments, the finger is flexed as a whole on the metacarpophalangeal joint, the extensibility of the middle and terminal phalanges being unaffected. When the traction is on the middle phalanx, this is flexed on the proximal phalanx; and if, as commonly occurs, the band is sufficiently shortened, the proximal phalanx is also flexed on the

Fig. 2968.—Dupuytren's Contraction of Palmar Fascia, Showing Marked Changes in the Palm, with Slight Contraction of Ring and Middle Fingers. (Notice punctate depression of skin at distal end of proximal phalanx of middle finger.) (Nichols.)

metacarpus, although the band may not be connected with this phalanx. The distal phalanges are flexed and connected with the contracted band in only a very small proportion of the cases. Fingers adjacent to one strongly contracted are frequently slightly bent from traction of the fibers of Gerdy or the web of the fingers.

Either hand may be affected alone, or both hands may be involved together. In 184 cases collected by W. W. Keen, the right hand was involved alone in 58, the left hand alone in 23, both hands in 103. In 49 cases examined by the writer the right hand was affected in 12, the left hand in 15, both hands in 22.

Any of the digits may be involved, but the thumb and index finger are rarely affected. The ring finger is much oftenest contracted, and the little finger in a large proportion of the cases; the middle finger is frequently involved, but not so often as the ring and little fingers. In 263 cases (214 collected by Keen, 49 observed by the writer) 572 fingers were affected in all, as follows: 12 thumbs, 24 forefingers, 93 middle fingers, 249 ring fingers, 194 little fingers.

One finger may be affected alone, or two or more fingers on the same hand may be contracted together. The commonest conditions are for the ring finger to be contracted alone, little finger alone, ring and little fingers, middle and ring fingers, in about the order

Fig. 2969.—Extreme Dupuytren's Contraction of Little Finger. (Nichols.)

stated. When two or more fingers on a hand are contracted, they are usually adjacent, though not always.

When both hands are affected, the contraction always or almost always begins in one hand before the other. Usually the two hands are affected to unequal degrees. Sometimes there is very little difference in the extent of the contraction in the two hands; in numerous other cases the hands are very unequally affected, one hand showing marked finger contractions while the other may exhibit only slight stigmata of the disease in the palm. The hand first affected is usually the one worse affected. The lesions are not exactly symmetrical in most cases, but have different locations in the two hands; thus, the ring finger of one hand and the ring and little fingers of the other may be the ones involved, or the ring finger of one and the middle finger of the other, and so on for a large number of possible combinations; still, in some cases the same digits are affected on the two hands. In the great majority of the bilateral cases, therefore, the two hands differ in the time of onset of the disease, the degree of the contractions, and the location of the lesions.

Both sexes are liable to the disease, but women are affected much less frequently than men.

The influence of heredity in the causation of the disease is marked, a hereditary or family history of the occurrence of the affection being obtainable in about a fourth or a fifth of the cases.

The disease develops not only in the hands of persons engaged in manual occupations, but also, in large numbers, in persons not engaged in manual labor, and even in persons completely idle.

Dupuytren's contraction is a disease of the adult and senile period of life, the favorite age of onset being from fifty to seventy years. Cases do, however, develop during the first half of life, and it is said that even congenital cases occur. It is possible that many of the cases alleged to have appeared at an early age were in reality cases of hammer finger, a condition that has only recently been distinctly differentiated. In 90 cases collected by Keen the ages of onset were as follows: after forty years, 47 cases; from thirty to forty years, 18 cases; under thirty cases examined by Nichols the ages of onset were as

follows: under twenty years, 1 case; from thirty to forty years, 7 cases; from forty to fifty years, 6 cases; from fifty to sixty years, 16 cases; from sixty to seventy years, 12 cases; over seventy years, 3 cases. The latter figures indicate that the disease is rare under thirty years of age.

The onset and development of Dupuytren's contraction are usually gradual and insidious. Rarely pain or other symptoms in the affected area may precede the appearance of the contraction. As a rule the disease has a definite period of development, and then remains stationary. The period of development of the contraction usually ranges from a few months to three or four years; occasionally the lesions may develop within a few weeks, while in other cases the process of contraction may continue for many years. Sometimes there is a certain amount of intermittency in the development of the contractions; the lesions develop to a certain degree, remain unchanged for months or years, and then have another period of increase. This is especially manifest in the bilateral cases, in which after full development of the lesions in one hand a quiescent period of perhaps years may elapse, when the other hand becomes affected.

Subjective symptoms, pain, tenderness, or abnormal sensations, connected with and located in the seat of the contraction occur in only a small proportion of the cases. In some instances the pain is worse or exists only during the early period, though it may occur at intervals after the full establishment of the contraction as well as during the period of development. The abnormal sensations are often an occasional stinging or pricking feeling in the affected region; also a sensation of numbness or itching, dull aching pains, or sharp shooting pains. Tenderness is occasionally present, especially from exposure of the projecting surfaces to irritation; a feeling of tension in the palm is sometimes noted.

The milder degrees of the disease do not cause trouble or discomfort, and only exceptionally are any of the cases attended with pain. The severer forms of the contraction cause material deformity and disability. Occupations requiring the use of the hand may be interfered with. The condition once established is permanent unless obviated by surgical measures.

The diagnosis of the condition from other affections of the hand is usually easy. The bent finger, the ridge in the palm corresponding to the contracted band, the rounded, callus-like indurations, the small wristward inversions of the skin, and the definite location of the lesions are characteristic features which even in mild cases distinguish the affection. Even faint stigmata of the disease are quite distinguishable. Contractions from tendon lesions do not exhibit the characteristic surface changes of fascia contraction. In cicatricial contractions there is the history of injury, the scar tissue, the absence of the typical features of Dupuytren's disease. Arthrogenous deformities are recognizable by the history, the anatomical features present, or the constitutional condition; arthroses may coexist with Dupuytren's disease, however, introducing an element of doubt as to the precise share either may have in the production of the deformity present. In contractions limited to the digital fascia, surface and palmar changes are absent. Hammer finger exhibits no palmar or cutaneous changes, and is sufficiently characteristic to be readily distinguishable; it is probable that some of the cases diagnosticated and recorded as Dupuytren's disease, especially among the alleged congenital cases and those stated to have developed in early life, were in reality instances of hammer finger.

The etiology of Dupuytren's contraction has not been satisfactorily determined, and very diverse theories as to its causation have been advanced.

One prominent theory, held among others by Dupuytren, is that the disease is induced by slight local traumatisms or by continuous use and irritation of the palm incident to manual labor. In probably a majority of cases there is a complete absence of any history of local causes to which the lesions are attributed. The assumption that in all cases a forgotten trauma must have occurred is not logically justifiable. Persons not engaged in manual occupations are as subject to Dupuytren's disease, indeed rather more so, than are persons who habitually do manual work, and the disease may develop in the hands of persons entirely idle. The nature of the occupation is not altogether a safe criterion, since the soft hand of the non-worker is more easily irritated by occasional unusual use or strain.

On the whole, the statistics of numbers of cases are adverse to the theory of the local traumatic causation of the disease. There are other considerations opposed to the theory of traumatic origin and in favor of the contrary view of the idiopathic origin of the affection. The left hand is not materially less susceptible than the more-used right, and the ulnar half of the hand is much more frequently involved than the radial half, which bears the brunt of use to an equal if not greater degree. The favorite age of onset is after middle life, years after the period of active labor begins. The marked influence of heredity, the limitation of the disease to definite longitudinal tracts, the secondary development of contractions in the other hand after one has become affected, are unexplainable on the local traumatic theory.

The possibility of the nervous origin of the disease is worthy of consideration. The marked predilection of the disease for the ulnar side of the hand shows to some degree a relation with the distribution of the ulnar nerve. The pricking or tingling sensation specified in most of the few cases complaining of pain is quite suggestive of the paresthesia of nervous lesions. The involvement of both hands, one being affected subsequently to and to a less degree than the other, may point to the operation of sympathetic (nervous) action in reproducing the disease on the side opposite to that first affected. In the majority of cases of Dupuytren's contraction there is no history of concomitant nervous disorder; and it would perhaps be difficult to show that in the comparatively few cases accompanied by nervous disease the coexistence is not merely incidental. While a neuropathic or trophic theory of the pathology of Dupuytren's disease is supported by some considerations, and is not improbable, it cannot be regarded as having sufficient basis for definite acceptance.

Dupuytren's contraction is one of the scleroses, a hypertrophy or hyperplasia of connective-tissue elements, and is hence to a certain extent allied to the visceral cirrhoses, as of the liver, kidney, and lungs, arteriosclerosis, and the spinal scleroses. Dupuytren's contraction, however, differs from the visceral scleroses in being sharply circumscribed while the latter are diffuse and general. Why the palm should be selected to suffer in this manner from irritants circulating in the blood, and especially why the hypertrophy should be limited to specific longitudinal fasciculi, does not appear.

Contractions of the plantar fascia have been reported analogous to those of the palm; induration or contraction of the penis, associated with Dupuytren's contraction, has also been observed. Keloid, fibromata, and cicatrices are allied in some respects to fascial contraction. The contraction of ligaments in talipes and arthropathies, and of cicatrices, also presents some analogies, especially with respect to longitudinal shortening.

Treatment.—The only hope of relief in Dupuytren's contraction rests in operative intervention, for which a variety of methods have been practised.

One of the most popular and efficient procedures is

that of *subcutaneous division* of the contracted fascial band, especially advocated by William Adams. A small straight tenotome is introduced between the skin and the band, and the latter cautiously cut downward. This is done at as many points as is necessary to free the finger and enable it to be straightened; as many as twenty or twenty-five punctures may be required. The sections are made along the entire band, from its proximal to its digital end, as needed. The hand is then dressed, with an anterior splint, with the fingers extended. The results of this operation have been very satisfactory in the hands of numerous operators. Before the days of antiseptic surgery it was doubtless the most advisable procedure, but with the introduction of aseptic technique many of the former objections to open operations have become obsolete. Even at the present time the subcutaneous method is preferred by some surgeons; Adams states that it is less liable to be followed by recurrence than the open operation.

Transverse division of the cord at one or more places, sufficient to free the finger, has been practised by some operators, followed immediately or after some days by the use of splints. Dupuytren and others have made open transverse incisions through both skin and band. In Goyrand's method the fascial band was exposed by a longitudinal incision through the overlying skin, and the band itself then divided transversely.

Excision of the fascia band in many cases is a rational and preferable procedure, though at times when the fascia is closely connected with the skin it may be difficult to separate it well. A longitudinal incision is made through the skin over the cord, and the band then carefully dissected out, after which the wound is sutured.

Wherever practicable—that is, when the contracted band is well marked and easily separable from the skin—it is probable that the band should be dissected out carefully through a longitudinal incision. But when the contracting tissues are poorly defined or the skin is extensively involved, multiple transverse sections of the band, open or subcutaneous, may be indicated.

The postoperative treatment is very important, consisting of extension by splints or apparatus for a period sufficiently long to overcome the contraction or the tendency to recurrence. Operators have varied as to the time allowed to elapse after operation before mechanical extension is begun, some applying splints immediately, others not for several days afterward. It is probable that no greater degree of extension should be applied immediately after operation than can be employed without too great tension being exerted on the wound. After healing takes place, firm extension of the fingers by splints or apparatus can be maintained for a few weeks, at first constantly, later intermittently, until a permanent result is obtained.

The final results of operative treatment of Dupuytren's contraction are generally satisfactory, though sometimes recurrence takes place.

Contraction of Digital Fascia.—The subcutaneous fascias of the fingers undergo contraction along with those of the palm in typical cases of Dupuytren's disease; and in some cases of hammer finger secondary digital fibrous contractions may perhaps be present. But aside from these, cases occasionally occur of fingers bent by hypertrophied and shortened bands of the digital fascia alone.

In diagnosis, finger deformities due to digital fascia contractions would have to be differentiated from those due to ankylosis, arthritic conditions, tendinous adhesions or shortening, cicatrical contractions, Dupuytren's contraction, hammer finger (shortened ligaments), and such conditions. The cardinal feature indicative of fascia contraction is the presence of a subcutaneous fibrous band evident to the senses; it is conceivable, however (though perhaps not possible), that cases might occur in which a shortened and unusually elevated tendon might to the examining finger be undistinguishable from a fascial band. Moreover, cases might occur in which the subcutaneous fibrous tissues might be sufficiently shortened to cause deformity but yet not be palpable as distinct contracting bands; such cases might present difficulty in making a definite diagnosis.

The obvious treatment of this condition would be to divide or excise the contracting bands.

Fig. 2970.—Deformity Resulting from Contracted Subcutaneous Digital Fascia and Other Lesions. (Nichols.)

Hammer Finger.—There is a well-marked class of contractions or anterior deflections of the fingers, not very uncommon, manifested especially by a flexion of the little finger at the proximal interphalangeal joint, which is of distinctive nature. The affection has received very little attention in medical writings. It was described and figured in 1846 by R. W. Tamplin, who attributed it to contraction of the skin. After that it was occasionally mentioned by authors, but the fullest studies of the subject are those of William Adams and William Anderson, both originally published in 1891. The condition has mostly been called "congenital contraction of the finger," but Anderson applied the term "hammer finger" to it. The latter is the preferable designation, as it is concise, has sufficient metaphorical significance, expresses the analogy of the condition to hammer toe, and is non-committal as to the pathology of the affection or as to its being in all cases congenital.

Two varieties of the affection may be considered: the developmental or congenital, and the acquired.

Developmental Hammer Finger.—This deformity typically consists in a flexion of the middle phalanx upon the proximal phalanx of the little finger at varying angles up to a right angle—usually at an angle of about 135°. Slight limitations to full extensibility of the middle phalanx of the little finger are common, but unless the flexion amounts to about twenty degrees or more it is hardly worth while to regard it as abnormal. Within their respective limits flexion and extension of the affected phalanges are unimpeded; but beyond them further extension is impossible without the use of unusual force. In most cases the proximal phalanx is unaffected; but according to Adams it is sometimes bent backward or superextended (the middle phalanges being flexed), as is commonly the case with the corresponding phalanges in old cases of hammer toe. The distal phalanges are also usually unaffected: but they are sometimes flexed instead of the middle phalanges, and in one case reported by Adams they were superextended, the middle phalanges being flexed. Some of the other fingers (especially the ring and middle fingers) are sometimes similarly affected in conjunction with the little finger, but to a less degree than the latter. In the congenital form the affection is usually bilateral, the hands being affected together though not always equally.

The skin over the anterior aspect of the finger is sometimes shortened or forms a longitudinal fold stretching across the concavity of the affected inter-

phalangeal joint, increasing the anteroposterior diameter of the proximal phalanx. According to Adams, there are often present subcutaneous bands of contracted fascia, centrally or laterally located, sometimes with fibers inserted into the skin; but according to other authorities fascia contractions are absent. The author has not been able to detect contracted fascial bands in any of the developmental cases of hammer finger which he has observed; and in the pure uncomplicated developmental form of the affection it is probable that fascia contraction plays no essential part. In some cases there is some secondary shortening of the flexor tendons of the finger. Often the distal end of the first phalanx projects slightly at the angle of the articulation, but there is no subluxation of the joint. The lateral ligaments of the joint are shortened, and there may be other developmental or secondary changes in the joint. The contraction is entirely unassociated with injuries or arthritic or paralytic conditions. The contraction is not the seat of any pain or other subjective phenomena, but in its extreme forms may cause considerable deformity, unsightliness, and inconvenience.

The affection is markedly hereditary. Numerous cases have been observed of its transmission from parents to children and of its coexistence in brothers and sisters. It is frequently associated with hammer toe, either in the same individual or in the family. It is not a very uncommon condition, but is not often brought to the notice of the surgeon; it is much less common than hammer toe. It is said to affect females more frequently than males. In 800 school children Anderson found two cases among boys and five cases among girls. Among 1,000 adult men Nichols found about five cases (one-half per cent.) of devlopmental hammer finger.

While this form of hammer finger may or may not be manifest at birth, it usually makes its appearance very early, probably in the first two or three years of life. Adults affected will state that their fingers have been bent, as far back as they can remember. Sometimes the contraction makes its appearance at a later age, even up to eighteen or twenty years, but always before maturity is reached. It is therefore a disease of the developmental period of life, and in that sense is congenital. The contraction slowly and continuously progresses for years, until the maximum is attained.

The essential pathological nature of hammer finger is only partially determined; opportunities for operation or dissection are not often presented. Several observers have regarded the flexed condition as due to shortening or contraction of the skin over the proximal phalanx; but this change in the skin, when present, is undoubtedly a secondary alteration and not the primary cause of the flexion. According to Adams, the deformity is due, partly at least, to shortened subcutaneous fascial bands. C. B. Lockwood, in a dissection of an amputated hammer finger, found a thickening and shortening of the fascia over the flexor aspect of the proximal interphalangeal joint, which caused the flexion; he did not state the condition of the ligaments. Other observers, however, have not found fascia contractions present, and they are certainly not an essential feature of developmental hammer finger, but only of secondary, occasional, and exceptional occurrence. The flexor muscles or tendons are not regarded as being the primary cause of the contraction, though they may be secondarily shortened. E. M. Little cut the tendons in one case, but without relaxing the finger; on the contrary, Anderson after cutting the other structures found that the flexors kept up the contraction.

The primary cause of hammer finger is apparently an abnormality, frequently hereditary, in the development of the component parts of the affected joint, resulting in a disproportion in the osseous, cartilaginous, and ligamentous tissues; the developmental abnormity results practically in a shortness of the lateral and anterior ligaments of the phalangeal joint, which interferes with full extension of the finger. The ligamentous shortening becomes manifest during the period of development. This is Anderson's view of the etiology of hammer finger, though he does not report any dissection. In a dissection made by Nichols the contraction was found due, chiefly at least, to much-shortened lateral liagments.

In long-established cases, in addition to ligamentous shortening, other changes are present; namely, alterations in the articular surfaces and shortening of the flexor tendons, fibrous tissues, and the skin over the proximal phalanx. These alterations are doubtless secondary changes, caused by the accommodation of these structures to the prolonged abnormal position. These secondary changes must be taken into account in operative procedures, as in old cases division of the lateral ligaments alone is apt not to be sufficient to correct the deformity entirely, as in a case operated on by Anderson and another by Nichols.

Why the little finger, and the proximal interphalangeal joint of this finger, should be the especial seat of this abnormity, is a point that is not clear. The cause of superextension of the proximal phalanges as reported by Adams is also obscure. Hammer finger is allied in many respects to hammer toe. It is a distinctive condition, *sui generis*, easily recognizable, and entirely different from Dupuytren's contraction of the palmar fascia.

Acquired Hammer Finger.—Nichols observed a very few cases of flexion of the little finger at the proximal interphalangeal joint exhibiting almost precisely the same external appearances that developmental hammer finger presents, but which developed in adult life; that is, were acquired rather than congenital. An acquired form of the affection is recognized in the literature only by Tamplin.

In the absence of dissections the cause and anatomical changes of these acquired hammer fingers are obscure. They are not due to ankylosis, subluxations, or other joint changes, to cicatricial contractions, to skin changes, nor to perceptible fascia bands. Tendinous lesions might be possible causes. The deformity is probably due to shortening of some of the fibrous structures about the affected joint; whether the ligaments or the more superficial fibrous and fascial tissues, or both, remains to be determined. If the latter, the tissues must be generally shortened, and not thickened into bands perceptible to touch. The association with Dupuytren's disease may indicate the action of a common cause tending to produce shortening of fibrous structures in different situations. The peculiar susceptibility of one particular joint is an obscure point.

Acquired hammer finger bears a certain relationship to contractions of the digital fascia. The distinguishing point between them is the presence of evident subcutaneous bands in the latter. The significant fact that the proximal interphalangeal joint of the little finger is the articulation exclusively or chiefly affected in developmental hammer finger, acquired hammer finger, and digital fascia contractions constitutes a common point of relationship between these three affections, and indicates the existence of unknown specific etiological factors that render this particular joint especially liable to such changes.

The diagnosis of developmental and acquired hammer finger should ordinarily present no difficulty. The cases, especially congenital cases, are quite characteristic in their appearance, seat, and history. Flexions of the fingers due to injuries, arthritic changes, paralytic or spastic conditions, cicatricial contractions, section of extensor tendons, are usually easily distinguishable by their respective characteristics. Contractions of digital fascia are distinguished by the palpable presence of fibrous bands. Deformities produced by adhesions of flexor tendons

or by fibrous ankylosis of the joints might be difficult to differentiate. To a certain degree the diagnosis, of the acquired form especially, is negative; that is, finger contractions of this type whose cause is obscure might for convenience be classed as hammer finger. Deformities due to Dupuytren's contraction are recognizable by an evident relation of the flexion of the finger with the palmar lesion; this relation is plainly demonstrable in Dupuytren's disease; although the two affections are entirely distinct, it is probable that cases of hammer finger have been diagnosticated Dupuytren's contraction, especially in alleged congenital cases of the latter affection.

Treatment of Hammer Finger.—The minor degrees of hammer finger do not cause sufficient trouble to require treatment. For the worse forms of the contraction treatment may be sought on account of the inconvenience or awkwardness of the bent finger or for the sake of appearance.

In young and mild cases, when the contraction is not too rigid and unyielding, passive motion and mechanical extension on a splint or special apparatus will often yield satisfactory results in the correction of existing deformity or the prevention of further deformity. To be effective and permanent such treatment must be kept up constantly and faithfully for a long time. The splint should be worn day and night for months, and then at night or at intervals, for a long time, until the persistent tendency to recontract is overcome. Special forms of apparatus have been devised for maintaining extension of the fingers.

In adults and cases of long standing, when the tissues are rigidly contracted and secondary alterations greatly augment the difficulties of treatment, the results of treatment are apt to be unsatisfactory. In such cases operative treatment is the only procedure offering any hope of relief. In considering the advisability of operative interference the liability of subsequent ankylosis from entering the joint, or of impaired mobility from interference with the tendons, should be borne in mind. Stiffening after operation on hammer toes does not affect the usefulness of the member. Stiffening of a finger in an extended position, however, is a material inconvenience and disadvantage and no improvement over the hammer condition. The finger joints are very apt to becom ankylosed by only slight injuries, and the risk and disadvantages of such a result or of unsightly enlargement of the joints should be remembered in considering operation. Recontraction is apt to occur.

Few cases of hammer finger have been operated on, so that data as to results or the best technique are scanty. The object aimed at is to divide all the structures causing the contraction. The shortened lateral ligaments should be cut, either through an open wound or subcutaneously. In inveterate cases a division of the ligaments alone may not suffice to free the finger, owing to secondary contraction of the skin, flexor tendons, and fibrous tissues. It will therefore be necessary to divide all the contracting structures—skin, fascia, tendons—until the finger can be straightened. Contracted fibrous bands may be divided subcutaneously, as recommended by Adams. After operation extension of the digit by splints or apparatus should be maintained for a long time to overcome all remaining deformity and to prevent recurrence. Passive motion of the joints should be practised early and frequently to obviate ankylosis. Perfect results are, however, difficult to obtain, though improvement may be effected.

Forcible divulsion was employed by Little in one case. Under full anesthesia the finger was forcibly straightened and the contracting tissues were ruptured; this was followed by the prolonged use of a splint, with good results except for some tendency to recontraction. In treatment of this kind in children care should be taken not to cause separation of the epiphyses of the phalanges.

In cases of extreme deformity and unsightliness amputation has been proposed and actually performed.

General Palmar Induration.—Cases are frequent in which the skin and subcutaneous fibrous tissues of the palmar surface of the hand and fingers are generally hardened, indurated, and slightly contracted, so that the fingers are held slightly flexed or arched on their metacarpophalangeal and phalangeal articulations, and are not easily capable of full extension. This condition is common in hard manual workers as the result of occupation irritation. It is also occasionally exhibited by old persons, in whom the skin may not be abnormally hardened, but in whom the fingers or some of them (especially on the ulnar side) are somewhat flexed by, apparently, a slight general shortening of the palmar fascias. This may develop as a senile change without antecedent occupation irritation.

Trigger Finger.—Also called spring finger, snap finger, jerk finger, stuck finger, doigt à ressort (French), schnellender Finger, federnder Finger (German), digitus recellens. Trigger finger is a condition in which a finger during flexion or extension, or both, is suddenly arrested in its movement, and then after the exercise of extra force is suddenly released and completes the movement of flexion or extension with a sudden jerk, resembling the action of a trigger or blade of a pocket knife.

This affection was first described in 1850 by A. Notta. Since then about 130 or 150 cases have been recorded.

The characteristic feature of the disease is the impediment to motion, the abrupt arrest of movement of the finger and its subsequent trigger-like release and sudden completion of movement (the "ressort"). The arrest always takes place at a certain point and angle, and may occur during flexion alone, during extension alone, or more frequently during both. Up to the point of arrest flexion and extension proceed normally, but at that point the motion is abruptly arrested and the finger seems to become set or locked at a sharp angle, often an acute or right angle. Then by an extra muscular effort the finger is suddenly released and completes its movement of flexion or extension with a sudden sharp jerk. The muscular exertion required to free the finger varies, sometimes requiring extreme effort, or even assistance from the other hand; one patient had to sit on the finger before the movement could be accomplished. At the instant of release a distinct click or sound can often be heard. Flexion is usually (though not always) more easily accomplished than extension, owing partly to the greater strength of the flexor muscles.

Pain, variable in degree and location, usually occurs associated with the condition, though exceptionally it is absent. In intensity it ranges from slight to excruciating. It is most severe at the time of the "ressort," but in some cases is excited by any movement of the finger. Tenderness on pressure may also exist. The seat of maximum pain is usually in the vicinity of the metacarpophalangeal articulation, but it may extend into, or be felt in, other parts of the finger, the hand, or even the forearm. Occasionally there is crepitation on movement of the flexor tendons, and various paresthesiæ have been observed, especially in the earlier stages of the affection.

In the great majority of cases (upward of seventy-five per cent.) a nodule can be plainly felt on the flexor tendon of the finger and movable with it, being manifestly attached to the tendons. This is in almost all cases situated near the metacarpophalangeal articulation, but in three or four cases such a nodule has been observed over the proximal or distal interphalangeal joint. In a very few cases a similar nodule has been perceptible, but did not move with the tendon, being connected with the tendon sheath. The nodosity plays an important part in the mechanism of the affection; still, in numerous cases it is

not to be felt. The impediment to motion is sometimes overcome by pressure on the nodé; also by manipulation of the distal phalanx.

The affection is uncommon. It may occur at any age, from three months (regarded as congenital), seventeen months, and two years, up to ninety years. It is much the most frequent in the adult period, however, from twenty to seventy years of age. It occurs in females rather more frequently than in males, in the proportion of about three to two. A similar trigger condition has been observed in the toes, knees, and other joints, and also in animals; and one or two cases have been reported in which lateral movements of the fingers exhibited the same kind of impediment.

Usually one finger alone is involved, but more than one may be affected, either at the same time or in succession. In one case all the fingers of both hands were involved. In some cases the abnormality occurs symmetrically on both hands. Of the two hands the right is much the more liable to the affection in the proportion of two to one.

The middle finger, ring finger, and thumb are the ones much the most subject to the affection, in about the order named; the index and little fingers are much less frequently affected. In the left hand, the thumb and middle finger suffer less frequently than they do in the right hand.

V. Carlier, who collected 105 cases of trigger finger, gives the following statistics as to the number of times each finger was affected:

	Right hand.	Left hand.	Total.
Middle finger.	32	9	41
Ring finger...	20	18	38
Thumb.	26	7	33
Little finger	6	3	9
Index finger..	8	1	9
	92	38	130

The joint at which the trigger condition is chiefly manifested is the interphalangeal articulation of the thumb and proximal interphalangeal joint of the other digits, the second phalanx in the position of arrested movement being flexed on the proximal phalanx. Sometimes, however, the distal interphalangeal joint is the one involved; rarely the metacarpophalangeal articulation.

The factor cited as causative of the condition in the greatest proportion of cases is occupation irritation, as in seamstresses, soldiers, brushmakers, etc. This effect of occupation irritation is held to explain the greater liability of the right hand to the disease. Another explanation of the effects of occupation attributes the trigger condition to the excessive use of single fingers, in much the same manner as writer's cramp and other occupation neuroses are produced.

A considerable proportion of the cases originate distinctly from trauma of the affected part, the injuries producing the particular inflammatory or other lesions necessary to set up the trigger condition.

The disease usually has a gradual onset, varying in symptoms and duration. The cases produced by trauma develop most rapidly, within a few days or two or three weeks after the injury. Other cases develop more slowly, over a period of weeks and months and even of years. The initial symptoms may be a slight inconvenience or awkwardness in movement of the finger; this difficulty gradually increases to the fully developed trigger condition. Vague pains appear in the affected part, increasing in intensity. Sometimes a rustling or grating movement of the flexor tendon is early felt, resembling the crepitation of tenosynovitis. In other cases paresthesiæ early appear in the region involved, as numbness, "going to sleep," formication.

The anatomical cause and mechanism of trigger finger have given rise to considerable discussion, and various explanations have been presented.

Most of the cases are undoubtedly due to lesions of the flexor tendons or their sheaths, especially those in which the nodule is perceptible. This nodule is in most cases attached to the tendon, near the metacarpophalangeal joint; it is of inflammatory, fibrous, or neoplastic (fibromatous, osteomatous, etc.) origin. As the tendon moves the nodule is caught at some point, as in transverse bands of the fascia or in constricted portions of the tendon sheath, so that motion is suddenly arrested; by further effort the nodule is forced past the obstruction and the movement is completed rapidly by the excessive muscular tension.

In a few cases it has been demonstrated that the lesions causing the trouble were situated in the tendon sheath, the tendon itself being normal. These lesions consist either of an annular or circumscribed constriction of the sheath, a thickening of the sheath, or a nodular growth in it, which interfere with the movements of the tendon within. Such lesions can be produced by inflammation, neoplasms, etc. In these cases a nodule may or may not be felt, but if present it does not move with the tendon. There may also be lesions of both the sheath and the tendon.

Thickening or stiffening of the synovial sac in such a manner as to interfere with its gliding to-and-fro movement between the tendon and its sheath has been advanced as a cause of trigger finger, and may possibly be a factor sometimes.

Some authorities have considered abnormal conditions in the phalangeal articulations to be capable of causing trigger finger. The particular abnormalities that have been mentioned in this connection are (*a*) abnormal configuration of the joint, (*b*) short lateral ligaments, and (*c*) projections at the side of the joint. It is conceivable how a certain surface configuration of the joint, as a projecting nodule or ridge or abrupt curvature, could produce a trigger-like action. Shortened lateral ligaments would obstruct the motion of the phalanx at a given angle. The possibility of such a trigger action of short lateral ligaments Nichols has demonstrated in a dissection of a hammer finger.

That some cases of trigger finger are of nervous origin and due to muscular spasm has been upheld by a few writers, especially Carlier. According to some views trigger finger is somewhat allied to writer's cramp and similar occupation neuroses, arising in various occupations requiring excessive use of particular fingers. While muscular spasm cannot be a common cause of real trigger finger, yet the affection may perhaps occasionally be of spasmodic nature.

The prognosis of trigger finger is generally favorable. Spontaneous recovery sometimes occurs, and the affection is quite amenable to treatment, though sometimes no improvement is obtainable.

Treatment of non-operative kind often produces good results, especially in the early stages of the affection. One of the most essential parts of the treatment is rest, by immobilization of the part on a splint. In inveterate cases operation is necessary. The seat of the trouble should be cut down upon; the nodule on the tendon or sheath should be removed and the sheath of the tendon should be slit open at any constricted portion. Simple incision of the tendon sheath in obscure cases may result in cure.

Muscular Affections.—The lesions of the muscles of the hand chiefly met with are the atrophies, paralyses, spasms, etc., caused by nervous lesions, considered below. Primary diseases of the muscles are rare here as elsewhere.

Unopposed action of a set of muscles, as after section of the tendons or paralysis of the opposing group, causes corresponding contractures.

Occupation muscular atrophy is an atrophy gradually developed in groups of muscles by continual use or

overuse incident to the occupation pursued. It has been observed in the hand and elsewhere in a few cases. It affects especially the thenar muscles in lapidaries and others, and also the hands of writers. It is regarded as more of myopathic than neuropathic origin, and is quite amenable to treatment by rest, electricity, tonics, etc.

Volkmann's paralysis,[17] so-called ischemic myositis or paralysis, is a somewhat obscure condition, whose exact etiology and pathology have not been absolutely established. Von Volkmann, who first described the lesion, considered it as essentially an ischemic myositis, due usually to tight bandaging after fractures, especially fractures of the forearm. It may occur also, though rarely, in the leg. In other words, it was due to the cutting off of the blood supply by the tight bandaging. Several arguments can be brought forward against this; first, it is impossible to produce the lesion experimentally by tying the blood-vessels alone. The nerve must also be included. Second, the paralysis has been observed when the bandage is loose. Third, the lesion occurs most frequently in young persons whose blood-vessels have good, elastic walls.

Possibly the injury is done, not by the bandage, but by the fractured bone ends. Various writers have emphasized the importance of injury to the nerves by the fragments. Certainly in the amputated forearm that I had the opportunity to dissect, the appearance of the hand muscles in gross and microscopically suggested the nerve origin.

The onset of the trouble is usually fairly rapid. Pain may or may not be present. The hand usually swells and becomes paralyzed, and the fingers are flexed or semi-flexed. The wrist may be flexed also. When the acute symptoms have subsided, the rigid flexion deformities persist, and the hand and forearm are shrunken. Active and passive extension are both impossible.

Treatment.—It appears from the diverse results of treatment by various authors that the lesion is not an exact pathological entity, and that probably some cases will recover with or without treatment. If the bandage used be too tight it should be removed. All measures for stimulating the circulation should be adopted. In view of the conflicting opinions as to the causation, the procedure of cutting down on the seat of the fracture and repairing damage to vessels or to nerves seems wise. The operation has been done with good results.

In the later stages various measures have been recommended—apparatus, removal of portions of the forearm bones, tendon lengthening, etc. Most of them will usually fail. In the case I dissected, the obstruction to extension lay in the intrinsic muscles of the hand, and was removed by division of bands between the flexor tendons and the proximal phalanges.

Occupation or *habit contractures* sometimes occur in those whose occupation requires the hand to be held or exercised or overused in prolonged or habitual positions, as a flexion of the fingers in drivers, etc. Such cases demand change of occupation and appropriate local treatment.

Nervous Affections.—The hand suffers severely and conspicuously in many nervous diseases, and so marked and characteristic are its functional and structural changes that its condition affords data valuable for diagnosis in various nervous affections. The primary nerve lesions causing the changes in the hand are seated in the nerve centers or in the nerve trunks of the upper extremity; only rarely in the hand itself, as in inflammation or injury of the nerves in the hand, or, perhaps, in occupation neuroses.

Paralysis of any or all of the groups of muscles pertaining to the hand occurs in general paralytic conditions, such as hemiplegia, anterior poliomyelitis, progressive muscular atrophy, and numerous others, and in inflammations or injuries of the nerves of the upper extremity. With the paralytic condition is usually associated atrophy, often extreme, of the affected muscles.

The primary effect of any paralytic condition is loss of the corresponding muscular function. Secondarily, from the unopposed action of the muscles antagonistic to the paralyzed muscles, or from the unequal degree in which different groups are affected, muscular *contractures* arise, which may cause various deformities. The contractures are at first of the nature of continuous or tonic spasms, and can be overcome by passive force. Ultimately the prolonged malposition causes vicious secondary alterations and ankylosis in the joints, with atrophic changes or arrested development in various structures resulting in disproportionate relations of the various parts of the member, so that finally the deformity becomes permanent and uncorrectible. Different nervous diseases produce different characteristic deformities of the hand, as the "claw hand" of ulnar paralysis, the "wrist drop" of musculospiral paralysis, the "preacher's hand" of cervical pachymeningitis, the club hand of infantile paralysis. *Tonic spasms* of the hand, not associated with paralysis, occur in tetany, tetanus, hysteria, and Thomsen's disease.

Occupation Neuroses.—These comprise a class of local functional nervous disturbances produced by the excessive use of definite groups of muscles in performing delicate and complicated actions necessitated in various pursuits, to which the hand from its usage is subject. These affections are characterized by tonic spasms or cramps, tremors, incoordination and ataxia, or pain, which are brought on when attempts are made to perform the habitual actions, so that these movements can be excuted only with difficulty or not at all. As a rule, other acts requiring equal delicacy and complexity of coordination can be performed with ease, the neurosis operating only against the particular movements that produced it. The occupation neuroses present no menace to life or the general health, but they are financially and psychically serious in that they may prevent their subjects from continuing in their accustomed vocation.

No anatomical changes have been demonstrated in these cases. Neuritis is sometimes present, but it is a complication and not an essential feature. The condition is a functional motor disorder and is sometimes styled a local neurasthenia. The affection may develop at any adult age; it is rare under twenty, a large proportion of cases develop between twenty and thirty, and many from thirty to fifty years. Occupation neuroses may attack persons in excellent physical condition, though those of a neurotic tendency or debilitated state are more subject. They develop insidiously, the first symptoms being a certain amount of stiffness, tremulousness, uncertainty, jerkiness, dull aching pain, fatigue, or weakness, during the acts at fault. These troubles slowly increase, until the neurosis is fully established, when on attempting to execute the customary movements the hand is seized with a cramp or tonic spasm, or involuntarily goes into jerky spasmodic or choreic movements, or its movements cannot be coordinated, or it becomes tremulous, or paretic, or the seat of a deep dull aching pain. The affection is chronic in its course. The prognosis is unfavorable so far as cure is concerned, as the neurosis is very difficult or impossible to eradicate. The symptoms can be easily ameliorated by rest and change of occupation, but even after long intervals the trouble almost invariably recurs upon resumption of the occupation that caused it.

The commonest and best known of the occupation neuroses is *writers' cramp*, which typifies the whole writers' cramp, musicians' (pianists', violinists') cramp, hammer cramp.

The diagnosis of well-marked cases of occupation neuroses usually presents no difficulty. The earlier

stages may not be easily distinguishable from the vague incipient symptoms of other nervous affections. A local neuritis may present symptoms simulating occupation neuroses; but in neuritis the motor or ataxic trouble is not so closely related to one particular set of movements, and the electrical reactions may be altered. The prognosis of neuritis is also more favorable.

If symptoms of approaching writers' cramp appear, prophylactic treatment is important. The act of writing should be made as comfortable as possible, by the use of an easy-writing pen (as a gold pen), a penholder that can be held with ease, smooth paper, and the adoption of such arrangements and position as are

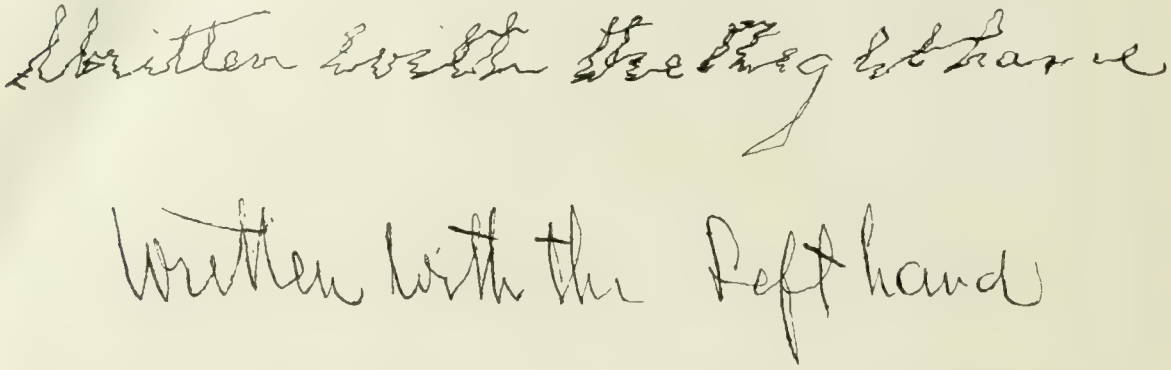

Fig. 2971.—Handwriting in a Case of Writers' Cramp (Tremulous Variety) of the Right Hand. The patient was a clerk and had been a good penman with the right hand; after the invasion of the neurosis he learned to write with the left hand. (Nichols.)

easiest for writing. The pen should be held lightly and grasped with as little force as is possible. The manner in which the penholder is held by the fingers should be changed. New sets of muscles should be brought into play, and the motions of writing should be altered as much as possible and carried on with the entire hand and forearm rather than with the fingers alone.

The best treatment of incipient or fully developed occupation neuroses is rest and suspension or change of the occupation. The symptoms readily yield to such treatment, but unfortunately these measures are not always practicable. General neurotic or debilitated conditions should receive appropriate treatment. Local massage, gymnastics, and electricity are useful. The unaffected hand may be used, after practice and training, to execute the movements impaired in the other hand, though in such cases the second hand often becomes itself affected by the neurosis. Various forms of apparatus have been devised for use in writers' cramp, for immobilizing the fingers involved, for holding the penholder and so relieving the fingers of the effort of pen-prehension, and for bringing new muscles into play in the act of writing. Such devices may be of service, but the substitution of typewriting machines for the pen is far more efficacious.

In chronic *lead poisoning* the extensor muscles of the hands are often paralyzed, producing the "wrist drop" characteristic of this condition; sometimes there is also in plumbism a swelling or ganglion on the back of the wrist. In *alcoholic polyneuritis* wrist drop may also occur, but less frequently than foot drop.

Injury or disease of the *brachial plexus*, produced by disease of the cervical vertebræ, in connection with dislocations of the shoulder, from the pressure of crutches, or other causes, results in motor paralysis, contractures, sensory disturbances, muscular atrophies, and other trophic changes, corresponding to the manner and extent in which the cords of the plexus are involved.

In division or other causes producing paralysis of the *musculo-spiral nerve*, there is paralysis of all the muscles on the posterior aspect of the forearm and the radial group of muscles, so that the wrist and proximal phalanges of the fingers cannot be extended, and the hand falls limply; this constitutes the condition of "wrist drop" which is a characteristic phenomenon in lead poisoning and other nervous affections. The middle and distal phalanges remain capable of extension from the action of the interossei and lumbricales muscles, which are innervated by the ulnar nerve. The paralyzed muscles may atrophy. Sensation may be lost on the radial portion of the dorsum of the hand, usually over the area corresponding to the thumb, index and middle fingers, and radial half of the ring finger; individual variations in the distribution of the nerves of cutaneous sensation in the hand are, however, frequent.

The *median nerve* furnishes cutaneous sensation to the palmar aspect of the thumb, index, middle, and radial half of ring finger, and innervates the pronator muscles, flexor carpi radialis, flexor longus pollicis, flexor sublimis digitorum, radial half of flexor profundus digitorum, abductor pollicis, opponens pollicis, outer head of flexor brevis pollicis, and the two outer lumbricales. Paralysis of the median nerve produced by section of it above the elbow or other cause results in loss of sensation over the area mentioned, atrophic changes in the muscles of the forearm and the thenar eminence, loss of power of abduction and opposition of the thumb, loss of flexion of last phalanx of the thumb, diminished power of flexion of the proximal phalanx of the thumb, and impairment of flexion especially of the index and middle fingers. The power of pronation is lost and the wrist is flexed only by the flexor carpi ulnaris.

Division of the median nerve at the wrist, below the separation of the branches to the muscles of the forearm, results in loss of power of abduction and opposition of the thumb.

Paralysis of the *ulnar nerve* causes loss of sensation over the ulnar third of the hand and over the little and ulnar half of the ring finger, anteriorly and posteriorly, loss of motor power of the muscles supplied by it (flexor carpi ulnaris, ulnar half of flexor profundus digitorum, the muscles of the little finger, the two ulnar lumbricales, all the dorsal and palmar interossei, adductor pollicis, and inner half of flexor brevis pollicis), together sometimes with atrophic changes, at times extreme, in the muscles affected. Adduction of the thumb and lateral movements of the other fingers are abolished; flexion of the proximal phalanges is interfered with, and these phalanges are held in extension or superextension. From paralysis of the interossei and two lumbricales extension of the middle and distal phalanges is lost or impaired, and these phalanges, especially in the little and ring fingers, are

held strongly flexed. The action of the flexor carpi ulnaris is lost. In closing the fist, the distal and middle phalanges are first flexed by the common flexors, and then the proximal phalanges are bent by the continued action of these muscles.

When the injury or lesion involves the distal portion of the ulnar nerve, near the wrist, beyond the branches given off to the flexor profundus digitorum and flexor carpi ulnaris, these muscles will escape paralysis.

The deformity known as "claw hand" (main en griffe) is produced by paralysis of the interossei and lumbricales, the common flexors and extensors being at the same time unparalyzed. As these muscles

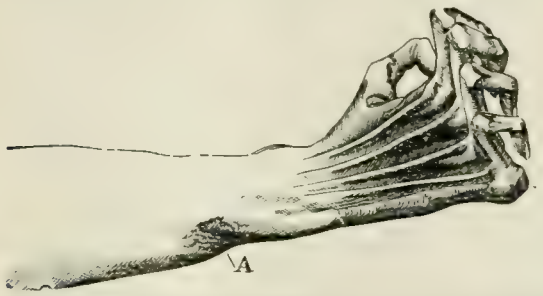

Fig. 2972.—Extreme Atrophy and Contractures from Paralysis of Ulnar Nerve (Caused by Wound at A); an Extreme Instance of "Claw hand." (Duchenne.)

are (with the exception of the two radial lumbricales) supplied by the ulnar nerve, claw hand is a characteristic consequence of paralysis of the ulnar nerve, and occurs in injuries of that nerve (Fig. 2972), and sometimes in progressive muscular atrophy (Fig. 2975), amyotrophic lateral sclerosis, syringomyelia, leprous neuritis, and other conditions. The action of the interossei and lumbricales is to flex the proximal phalanges and extend the middle and distal phalanges besides acting as abductors and adductors. Paralysis of these muscles results in a superextended position of the proximal phalanges (from the unopposed action of the extensors) and strong flexion of the middle and distal phalanges (from the action of the common flexors); this position of the hand is the one to which the term claw hand is applied. Along with this paralytic and contractured condition, extreme atrophy of the paralyzed muscles is often present in claw hand, the palm being hollowed out, and the interosseous spaces on the dorsum of the hand being sunken so as to form deep grooves.

Combined paralysis of the ulnar and median nerves, the musculospiral nerve being normal, results in the deformity known as the "preacher's hand" (main du prodicateur emphatique), from its supposed resemblance to the emphatic gestures of public speakers (Fig. 2973). The unopposed action of the extensor muscles causes the hand and proximal phalanges to be habitually held in a position of marked extension and superextension. The "preacher's hand" occurs especially in hypertrophic cervical pachymeningitis, though it occasionally appears in other nervous diseases.

Glossy skin is a rare trophic change sometimes resulting from wounds or other lesions of nerves, which affects the fingers especially. The digits, or one or two of them, are smooth, shining, and glossy, devoid of hair, pinkish or blotched as if by chilblains, and the surface of the skin lacks its natural linear markings. Trophic changes in the nails also occur. The lesions are the seat of burning pain and neuralgia.

Vasoneuroses.—There are some allied conditions which along with prominent vascular phenomena present pronounced neuropathic features, and hence have been classed as vasoneuroses. Some of them, notably Raynaud's disease, are more probably due to an actual anatomical lesion of the blood-vessels—a thickening of the arterial walls.

Raynaud's disease (peripheral gangrene, symmetrical gangrene) is a rare condition characterized by small circumscribed areas of vascular disturbance or ischemia, running on to gangrene, associated with severe neuralgic pains. The lesions are usually several in number, situated on the fingers or toes, sometimes the face; almost always they are bilateral and symmetrical. In the milder cases or earlier stages the lesions consist of small local areas of anemia ("local syncope") or of passive congestion ("local asphyxia").

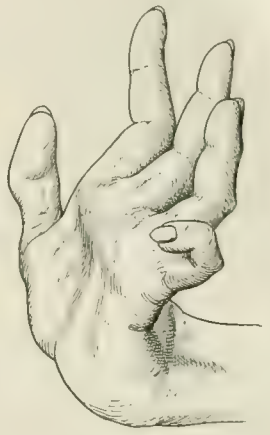

Fig. 2973.—Characteristic Position of the Hand in Hypertrophic Cervical Pachymengitis—the "Preacher's Hand." (Meillet and Richer.)

In the severer cases circumscribed moist black gangrenous patches develop; after the slough separates an ulcer is left that heals very slowly. The course of the disease is very slow and protracted, the lesions requiring weeks or months for their evolution and repair. The necrotic process has been known to cause complete spontaneous amputation of the ends of the fingers. In treatment, analgesics are required for the relief of pain. In the earlier stages, warmth, protection and *absolute* rest may avail to avert the impending disaster. Local treatment aims at promoting the separation of the slough and stimulating the healing process; this is accomplished by excision of the sloughs, antisepsis, etc.

Vascular Spasm.—In the rare condition sometimes termed "dead finger" one or more fingers undergo sud-

Fig. 2974.—Characteristic Appearance of the Hand ("Ape Hand") in Progressive Muscular Atrophy. (Meillet and Richer.)

den, repeated, and transient vascular spasm, so that they become white, bloodless, and cold. The paroxysms last a few minutes, hours, or even days. At times the blanching is preceded by lividity, and is occasionally accompanied by dull pain. The affection was first described by Allan McLane Hamilton in 1874, and since then a few cases have been reported. The treatment is by galvanism, nitroglycerin, or other vasodilators.

Progressive Muscular Atrophy.—The hands suffer early, characteristically, and severely in this disease,

either successively or simultaneously. The muscles of the thenar eminence are usually the first to be affected; they gradually become atrophied and paralyzed, producing a peculiar flatness of this region. The hypothenar muscles soon become similarly involved. At this stage the hand appears long, thin, and flat, and the thumb lies parallel and in the same plane with the other fingers; the hand in this condition has been likened in appearance to that of the ape (Fig. 2974).

Later the interossei and lumbricales atrophy and become paralyzed, resulting in corresponding loss of the power of abduction and adduction of the digits, flexion of the proximal phalanges, and extension of the middle and distal phalanges. If the flexor and extensor muscles in the forearm are at this stage unaffected, "claw hand" will result (Fig. 2975), though, as the muscles of the forearm usually become involved early, this deformity does not very often occur in progressive muscular atrophy.

Fig. 2975.—Claw Hand of Moderate Degree in Progressive Muscular Atrophy. (Meillet and Richer.)

Fibrillary contractions occur in the affected muscles. Contractures are not usually present to a marked degree.

Syringomyelia (Morvan's disease) involves especially the upper extremities, and is manifested by paralysis and atrophy of muscle groups, varying in situation, paresthesiæ and anesthesia (especially to temperature and pain) in irregularly distributed patches, and trophic changes. Some cases of syrin- beginning with atrophy and paralysis of the thophy, hypothenar, and interosseous muscles of the haena producing claw hand; the paralysis later proceeds un the forearm. Enlargement of joints (frequently the wrist) occurs, similar to Charcot's tabetic arthropathy. Edema, vesicles, bullæ, ulcers, onychias, recurring painless whitlows, and even extensive gangrene and mutilation about the fingers and hand may occur. In a few instances general hypertrophy of the hand has been observed, and in a few others Dupuytren's contraction has been present.

Tetany affects the hands conspicuously. Intermittent paroxysms of tonic muscular spasms occur, associated with pain and paresthesia. The paroxysms last for from a few minutes to a few days and may persist even during sleep; the intervals between the paroxysms vary from hours to months. The mechanical and electrical irritability of the muscles is increased, and pressure on the nerve trunks and arteries excites an attack (Trousseau's symptom). The position assumed by the hand during the spasm depends on the group of muscles affected, but is usually one of flexion. Often the hand assumes the conical shape of the accoucheur's hand about to be introduced into the vagina; the fingers are flexed at the metacarpophalangeal joints and extended at the other joints, the hand is narrowed and the thumb adducted. Sometimes the fist is forcibly closed by general flexion, the thumb being pressed into the palm and the other fingers flexed upon it. Rarely the fingers are extended and separated.

Hysteria.—In this condition the hand, like other parts of the body, may be involved in a variety of ways, by hyperesthesias, anesthesias (often dissociated), slight wasting, vascular phenomena (as flushing, pallor coldness, ordinary edema, cyanotic or "blue" edema), paralyses, sudden temporary loss of power in the muscles, tremor (simple or intentional), contractures, etc. Hysterical contractures of the hand may be temporary or persistent, and usually involve the flexor muscles, though sometimes the extensors are affected. Sometimes the contractures are extreme and very firmly fixed, not yielding to sleep or a mild degree of general anesthesia; they may continue for months, and cause permanent damage by setting up secondary joint changes.

Paralysis agitans is usually manifested in the hand in a very characteristic fashion. In typical cases the fingers are flexed at the metacarpophalangeal joints and the pulp of the thumb is opposed to that of the index finger; by the constant tremor the opposed thumb and index finger are kept continually rolling over each other, producing the movement described as "pill-rolling." The tremor is usually less during voluntary movements. Muscular rigidity of the digits and hand is often present.

Athetosis, or posthemiplegic chorea, is a peculiar motor affection of the fingers and toes that occurs most frequently as a sequela of infantile hemiplegia and infantile palsies, less frequently after hemiplegia in adults. It is manifested by slow and deliberate forcible involuntary movements of the digits, in extension, flexion, abduction, and adduction, which take place successively and incessantly, even during sleep. The movements may be complicated and peculiar, and may lead to distorted positions of the hand; they can be only partially and for a short time controlled by the will, and the fingers cannot be permanently kept in any fixed position.

The *treatment* of nervous affections of the hand is in general that of the cause or of the general condition producing the local trouble, together with measures to improve the local condition when no general amelioration is possible.

In wounds in which nerves leading to the hand are divided, the ends of the severed nerve should be carefully sutured together with catgut. If this is not done at the time of the injury, secondary suture, even after months or years, may restore the function of the nerve. If a portion of a nerve is destroyed and the ends cannot be approximated by stretching, plastic procedures or transplantation may be tried.

Developing or impending paralysis and atrophy of muscles and the resulting contractures and deformity may perhaps be arrested, retarded, or diminished by the use of electricity, massage, exercise, passive movements, etc. When deformity is fully developed there is usually little possibility of accomplishing any material improvement, though sometimes the local condition can be somewhat bettered. Thus, division or lengthening of the tendons of contractured muscles sometimes improves deformity and motion. In some cases shortening of the tendons of partially paralyzed muscles, as the extensors, may improve their action. Tendon transplantation, that is, the transference and joining of tendons of non-paralyzed muscles to those of paralyzed muscles, has been tried in the hand in a few cases, in some with good results, but the operation is not usually advisable. In some cases the use of mechanical apparatus is beneficial. Local trophic changes of inflammatory or necrotic character demand appropriate treatment.

Senile Changes in the Hand.—In old age the skin and subcutaneous tissues often become atrophied and thinned, diminishing the size of the hand and fingers. Joint changes are often present, and have been referred to above; they comprise chiefly enlargements (relative or absolute), ulnar deflections, changes in the thumb joint, and other lesions which merge into conditions of rheumatoid character.

Occasionally general palmar induration (as already described) is observed. Trophic changes in the nails —longitudinal ridges ("reedy nail")—sometimes occur. Senile warts (verruca senilis) may develop on

the hands as elsewhere; they may be flattish or elevated, pigmented or non-pigmented, sometimes fatty. The back of the hand is a favorite seat for keratosis senilis, which is manifested by warty projections in the form of small papules or larger flattish plates, greasy plates or patches, branny scales, pigmented spots, or in some cases thickening of the entire skin; sometimes the skin of the back of the hand is converted into a dense horny plate. This condition may run into epithelioma. Tremor of the hand, merging into paralysis agitans, is a common senile condition.

Condition of the Hand in General Diseases.—The changes exhibited by the hand in a large number of general diseases have been already detailed, so that there is little to be added on this subject. In anemic conditions the hand is pale, cold, dry, and the nails are pale. In conditions of vascular relaxation and atony, weak circulation, or lowered blood pressure, the skin is clammy, cold, purplish, or mottled. In cardiac disease the hands may be congested, cold, clammy, or edematous, and the fingers may be clubbed. In nephritis the hand is dry, pale, edematous. In tuberculosis the hand may be emaciated, hot, dry, or sometimes clammy, and the fingers are occasionally clubbed or blunt. Clubbed fingers may occur in other forms of pulmonary disease. The hand is dry and shrivelled in diabetes. Onychias may follow severe acute diseases. In typhoid fever the palms of the hands (and soles of the feet) are usually dry, parchment-like, of a yellow to brownish color, and during convalescence are the seat of active desquamation. In certain forms of idiocy the skin of the hands is loose, wrinkled like a washerwoman's, and looking too large for the hand, while the finger tips are tapering and conical.

J. B. Nichols.
Leonard W. Ely.

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Hanging.—See *Strangulation.*

Hansen, Gerhard Henrik Armauer.—Born July 29, 1841, in Bergen, Norway. From the first he was specially interested in the study of leprosy and upon completing his medical studies in 1869 he was appointed assistant physician to the Lungegaard Leper Hospital. He then spent some time in Vienna and Bonn in microscopical studies and on returning to Bergen undertook a series of investigations of leprous lesions and was rewarded by the discovery, in 1873, of the lepra bacillus. He did not confine himself, however, to a pathological study of leprosy, but labored clinically and by the promotion of legislative control to extirpate the disease. Before his death he had the

Fig. 2976.—Gerhard Henrik Armauer Hansen.

satisfaction of knowing that leprosy, formerly a widely prevalent affection in his native land, had become a comparatively rare disease. He died suddenly February 12, 1912.

Among Hansen's contributions to the literature of leprosy were the following: "Zur Pathologie der Lepra," Archiv f. Syph. u. Dermat., 1871; "Bidrag til Spedalskhedens Karakteristik," Nordisk med. Arkiv, 1869–1870; "The Leprous Diseases of the Eye," Christiania, 1873; "On the Etiology of Leprosy," Brit. and Foreign Med.-Chir. Review, 1875; "Studien über den Bacillus lepræ," Virchow's Archiv, 1882; "Leprosy in its Clinical and Pathological Aspects," Bristol and London, 1895. T. L. S.

Haplosporidia.—Neosporidia with a very simple life history, undifferentiated cell plasma, and uninucleate spores without polar capsules. These sporozoans are parasitic in fishes and invertebrates. See *Protozoa.* A. S. P.

Harbin Hot Sulphur Springs.—Lake County, California.

Post-office.—Harbin Springs. Hotel.

Access.—Take the southern Pacific ferry at the foot of Market Street, San Francisco, or the train at 16th Street, Oakland for Calistoga; thence a twenty-mile automobile ride brings one to the springs. Or via Monticello Steamship Company's fast steamers to Vallejo, and the San Francisco, Napa and Calistoga (Electric) Railway—the Napa Valley Route—from Vallejo to Calistoga. The location is at the base of a spur of the Coast Range of mountains, 2,000 feet above tide water. Lake County has been justly named the Switzerland of America, and it would be difficult to find a more delightful and picturesque location than that of the Harbin Springs. The mountain air is very invigorating and not subject to extremes of heat or cold, the mean temperature being 70° F. The waters are sulphurous and saline, the principal spring flowing 1,500 gallons per hour. There is also a small chalybeate fount yielding only sixty gallons per hour. The sulphur spring has a temperature of 122° F., and is used for bathing, for which

excellent facilities have been provided. Following is an analysis of this water:

One United States Gallon Contains:

Solids.	Grains.
Sodium chloride	23.05
Sodium carbonate	5.42
Sodium sulphate	10.19
Potassium carbonate	1.74
Magnesium carbonate	6.18
Magnesium sulphate	11.94
Calcium carbonate	9.10
Calcium sulphate	14.63
Ferrous sulphate	1.75
Arsenous salts	.07
Alumina	1.60
Silica	2.76
Organic matter	Trace.
Total	88.43
Gases.	Cu. in.
Carbonic acid gas	4.26
Free sulphureted hydrogen	11.74

It is said that much benefit accrues from the use of this water in chronic rheumatism and gout and other articular affections, as well as in certain varieties of skin diseases.

The chalybeate spring shows the following mineral ingredients:

One United States Gallon Contains:

Solids.	Grains.
Sodium chloride	7.50
Sodium carbonate	14.22
Sodium bicarbonate	1.45
Sodium sulphate	5.25
Potassium chloride	Trace.
Potassium carbonate	1.73
Magnesium carbonate	4.16
Magnesium sulphate	6.11
Calcium carbonate	2.07
Calcium sulphate	Trace.
Ferrous carbonate	1.90
Alumina	.73
Silica	1.41
Organic matter	Trace.
Total	46.53

Carbonic acid gas, 9.34 cubic inches.

These analyses were made by Dr. Winslow Anderson.

This water is clear and sparkling, and has a pleasant taste. It is tonic, antacid, diuretic, and aperient, and is useful in dyspepsia, anemia, chlorosis, chronic malarial poisoning, and wasting diseases. In addition, there are two other springs of some importance; they are known as the "Magnesia" and the "Arsenic" springs. The last-named spring has gained quite a reputation in syphilitic and skin diseases, and glandular indurations. Here are fine fishing and hunting in season. A variety of amusements are provided for the guests. Emma E. Walker.

Hardy, Alfred.—Born in Paris, France, November 30, 1811. He studied medicine in his native city and received his doctor's degree in 1836. In 1846 he was appointed Physician of the Hôpital de Lourcine, and in 1851 he was given the same position in the Hôpital Saint-Louis. After a competitive examination he was made Agrégé of the Faculté de Médecine, and in 1867 he was appointed to the full professorship of internal diseases—a position which he held up to 1886. He died on January 24, 1893.

Hardy's place in the history of medicine is chiefly that of a successful worker in the field of skin and related diseases. He appears to have written very little, as nearly all the treatises published under his name were prepared by his pupils. The following are the titles of the more important of these publications: "Leçons sur les maladies de la peau professées a l'Hôpital Saint-Louis," edited and published by Léon Moysant and Almire Garnier, Paris, 1859–1860; "Leçons sur les affections cutanées dartreuses," edited and published by Pihan-Dufeillay, 1862; "Leçons sur la scrofule et les scrofulides," edited and published by Jules Lefeuvre, 1864; and "Leçons sur les maladies dartreuses," edited and published by Léon Moysant, 3rd edition, 1868. (Translated into English by Henry G. Piffard, New York, 1868.)

A. H. B.

Harelip.—Unlike cleft palate, this may be regarded as a strictly congenital malformation. It is a deformity that, from its peculiar prominence, has brought more sorrow to the hearts of parents than perhaps any other of nature's defects. To the surgeon it has been the source of more thought and care as regards the operation for its relief than are demanded by many surgical problems of far greater importance.

Like cleft palate, it may be looked upon as an arrest in fetal development, confined, with very rare exceptions, to the upper lip. When situated in the lower lip, there are many deformities that may coexist with it, such as combined fissure of the lower jaw and tongue, and a variety of other like complications. Sir William Fergusson speaks of several cases of this kind which has been observed by himself and other in their practice.

Associated with upper harelip are sometimes remarkable deformities about the face; for instance, the

Fig. 2977.

fissure my extend up along the nose on one or both sides to, or into, the eyelids, or it may extend out on one or both sides from the angle of the mouth, and may implicate Stenson's duct, a very unpleasnat complication.[1, 2] Though these conditions are rare yet most brilliant results have followed operations done intelligently and on modern methods.

Mason speaks of a cyanotic condition of the child. This condition, which I have also observed, is, at times, cured by the operation for closure of the fissure. Mr. George Lawson gives the explanation that during the lull in the circulation, in cases in which faintness occurs, the foramen ovale becomes closed and thus the double current is established.

The pathology of harelip is a subject into which the narrow limits of an article like the present one will not permit me to enter except in the most superficial manner. M. Coste [2] (Mason[3]) states that the mouth is formed between the twenty-fifth and the twenty-eighth day of fetal life. The frontal lobe becomes much enlarged, and shows a great hollow which divides into two smaller lobes, called by him the incisive centers, and from which the incisive bones and the middle portion of the upper lip are developed. The centers for the superior maxillæ, which form the lateral

parts of the upper lip, converge one toward the other, and come nearer to each side of the corresponding incisive center. At the fortieth day the two incisive centers, in the substance of which the incisive teeth are developed, unite one to the other in the middle line and thus complete the central portion of the upper lip. Thus, if the two lateral portions do not unite with the incisive portions, we have a double, or bilateral, harelip; if only one of these sides fails to unite, then we have a single, or unilateral, harelip. Stone[4] in the American Practice of Surgery, gives an excellent reference to the Etiology. I would also call attention to a very valuable contribution on "Ectopia, of the Pituitary, with other Congenital Anomalies of the Nose, Palate, and Upper Lip," by Alexander R. Tweedie and Arthur Keith.[5]

I have, in a few of my earlier operations, removed the intermaxillary bone, and, on examination of it, have noted an absence of the lateral incisors. This, I believe, has been the experience of most surgeons who have given careful thought to the question whether this island contained all of the upper incisors or not. In two cases that I examined a few years after the operation for cleft palate, in which I had saved the intermaxillary bones, I found in each instance an irregular lateral incisor on the right side, back of the regular row of teeth.

Etiology.—Fergusson, Demarquay, Gurdon Buck, and others report a large number of cases which illustrate the fact that harelip appears in some families through many generations, and I have observed this in the record of my own cases. Like webbed fingers and toes, harelip is often seen without any evidence of consanguinity being present.

There are few surgeons, I suspect, who have examined cases of harelip carefully, who have not been impressed with the effort so often made by mother or nurse to prove that the deformity is entirely due to some fright which the mother has experienced and which in her estimation has produced its effect upon the child in utero. Maternal impressions may be one of the factors in the production of harelip, and yet evidence of such cause is so often wanting as to lead us to doubt, and then it cannot be denied that when these impressions are analyzed it is found they have occurred long after the completion of the embryonic development.

Acting early upon the suggestion of the late Sir Wm. Fergusson, I have examined many lips and jaws for fissure, and have frequently found slight notching or partial defects on the mouths of one or the other of the

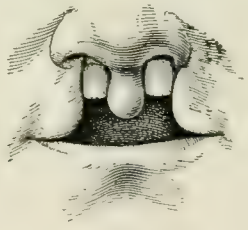

Fig. 2978.

parents. I have frequently had occasion to call the attention of my class to this point in the study of these cases. I have noticed that close pregnancies form a factor in causing this deformity. In connection with these cases it is not unusual to see in the same patient extra thumbs or fingers, spina bifida, and the like. The late Professor Alden March had a child brought to his clinic, for relief of harelip, who had cleft palate, an extra toe and finger upon each foot and hand, double hernia, and club foot.

Accidents, bites of dogs and other animals, treatment of nevi, and other surgical conditions may result in a temporary form of harelip, which may be said to be cured generally in the final treatment given to such lesions. In the case of Miss C——, aged six, suffering from nevus on the upper lip, whom I had treated in various ways without complete success, the final injection of a solution of tincture of iron produced a slough resulting in a fissure such as is seen in Fig. 2977, but which was closed with scarcely any scar by means of two silver harelip pins.

Fig. 2979.

A considerable number of cases is met with in which the kind of harelip is of the double variety, as seen in Fig. 2978, from Mason. In this variety the fissure may be very slight on one side and yet complete on the other, or, in cases in which there is a double fissure of the alveolar arch, as in cleft palate, we may have the horrid horn-like projection as seen in Fig. 2979 from Mason, and in one of my own cases, Fig. 1409 in vol. iii.

Cases of median harelip have been recorded by surgeons, but they are exceedingly rare, and their existence has even been doubted by some. In the autumn of 1883 there was brought to my clinic a female child (two and one-half years of age) in whom a cystic tumor at the tip of the nose was

Fig. 2980.

complicated by a complete median fissure of the upper lip. Fig. 2980 (from a sketch of the little patient) shows the case very well. Sir Wm. Fergusson has very justly remarked that, after the operation has been completed, one cannot judge correctly as to whether the case was originally one of a median fissure or of double harelip, for many cases of the latter defect, when operated on, show a decided tendency to the formation of a cicatrix in the middle line. Fig. 2981 one of my own cases, and quite as bad a case of double harelip as I have ever operated upon, shows this condition clearly. It is a singular fact that in these various kinds of fissure in the upper lip there is really very little loss of substance. One finds this to be true by merely approximating the soft parts temporarily.

Regarding the period of life when it is best to operate, in cases of harelip, much has been said by the older operators, but with little unanimity of opinion; some advising inter erence in infancy, others preferring to wait until advanced childhood. At the present time, I am of the opinion that modern surgeons prefer the early operation. My own experience teaches that a good time for the operation is when the infant is about six weeks old, especially if the child be healthy. In a case of double fissure perhaps it is well to wait until the child is six or seven months old, especially if the vomer or intermaxillary or premaxillary requires attention. Greater experience

convinces me that there are quite a number of strong infants that will bear the operation anywhere within two weeks after birth, when doing well otherwise.

In severe cases of double harelip I prefer to operate on one side at a time and to save all that is possible of the island or intermaxillary bone. In operating upon one side at a time, the first should be allowed to become firmly healed before we resort to the second operation. Ordinarily, this interval would amount to at least two months. I sometimes in these cases give to the skin covering the island the form of a square, and then, making flaps from the upper lip and cheeks on each side, secure a good, full lip, one

Fig. 2981.

which does not appear at all constricted. More attention should be given to the lateral incision out from the angle of the nose into the well-loosened cheek. I am convinced that in doing the operation we should pare the edges of the fissure freely, but not throw the pieces away—that is, not finally detach them; therefore, I believe that the operation which embodies this principle is the best.

Operations upon the adult are exceedingly rare, and are then generally performed for the purpose of improving an imperfect result following an early operation. In a few instances I have been obliged, for such a reason, to operate on an adult, and here one should exercise great care in securing thickness of edge of incision and loosening attachment to bony structures of the cheek.

In operating for harelip we should in all cases be sure to loosen well the attachment of the cheek to the alveolar process; there should be perfect freedom of movement, and no restraint put upon the parts when the pins or sutures—whichever may be selected—have been introduced. This is generally best done with a long, blunt-pointed tenotome—or small sharp-pointed scissors through as small an incision as is possible.

The position of the infant at the time of operating is a point of much importance. If the child is strong, I believe it safe and wise to give chloroform, or whatever anesthetic the surgeon considers to be the best. In recent years I have come more to using sulphuric ether. It is necessary to have an experienced anesthetist. It is better that the infant should have too little than too much of the anesthetic.

Having the child held by a good nurse or competent assistant—as is spoken of by so many writers—is often the easiest and best for the operator; but I am much in favor of placing the little one on a narrow, firm table of proper height, around which the assistants can work more at ease and not be in the way of each other. Standing on the right side of the table and patient, the operator proceeds to free or loosen the fissure on each side, as I have already stated. After this has been thoroughly done, he directs an assistant, opposite to him and at the head of the child, to grasp the left side of the fissure between the forefinger and thumb of his left hand, and then, with his right forefinger and thumb, to hold the right side in the same manner. The surgeon may now, with the so-called harelip forceps, or simple forceps, grasp one edge of the fissure, and, introducing a sharp-pointed narrow knife at the point of the cleft nearest the nose, carry the knife from above downward toward the vermilion border of the lip. He should then repeat the same steps on the other side, in each instance removing sufficient tissue to give good, broad surfaces for mutual contact. In a simple harelip I often pare the edges of the fissure with a strong pair of curved scissors, carrying out the principle embodied in Fig. 2984.

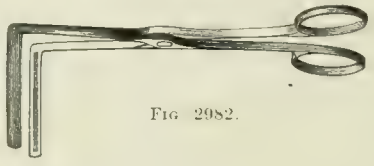

Fig. 2982.

Thus far, if the assistant's thumbs and fingers are not too large, and if he performs his part well, but little blood will have been lost. I consider the compressors of the upper lip for controlling hemorrhage, spoken of by some authors, as really not necessary, but if they are to be employed I would recommend an instrument like that shown in Fig. 2982 (from Mason).

The next step in the operation involves the closure of the fissure. It must ever be borne in mind that the vermilion border of the lip should be well preserved, with no sliding upward or downward on either side, and also that there ought not to be any notching.

As to the kind of suture that should be employed, I must say that my preference is for the silver harelip pins. In introducing them, I prefer that the first should be inserted nearest the vermilion border; it should be passed from the left to the right side of the fissure, and the greatest care should be exercised to bring the parts into good apposition. Of course, these steps may be modified or reversed if there is a single right-sided fissure, or if the surgeon stands in front of the child. Fig. 2983 (from Mason) illustrates

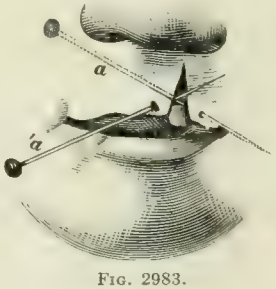

Fig. 2983.

my point. The pin should be introduced at least a quarter of an inch back from the freshened edge of the fissure and it should pass obliquely through the edge of the lip, but should not include the mucous membrane; it should then enter the opposite side and emerge in the same manner. Now, around this pin put a figure-of-eight silk ligature, not too tight, as some allowance must be made for swelling. Then, next above this first pin, introduce in a similar manner one or two more, as may be needed. If two are used, it is well to bring them together by one ligature, crossing from one pin to the other, as by adopting this plan one is not likely to get so much of a slough—that and ulceration being the two great dangers associated with the employment of silver pins.

Sometimes it is necessary to introduce between the

pins a few fine superficial silk sutures, and also to place two or three in the mucous membrane and one in the vermilion border of the lip, not leaving them in for more than twenty-four or thirty-six hours. In the case of the mucous membrane I prefer to use fine catgut sutures, and I then leave them undisturbed.

After the pins have been introduced the points should be cut off with bone forceps, and a small portion of absorbent cotton should be put under each end. They are not to be left in longer than three days, as a rule, and should always be watched with care to prevent ulceration or sloughing. It is better to take them out too soon than to leave them in too long. Of late I have used silkworm gut instead of pins—there is less likelihood of scar resulting—and in bringing the parts together in the upper angle, to relieve the flattened nose, it can be carried deeper with a good curved needle, and in many ways is handled easier.

Some surgeons prefer simple silk, others silver wire; then, besides, many other devices have been suggested. As stated in my article on cleft palate surgeons differ greatly as to the kind of suture to be employed. I am greatly impressed with and desire to endorse the method of introducing the sutures suggested by Mumford[6] (Fig. 2984) and I can see no reason why good, reliabel sterile catgut is not preferable. I take it that few surgeons rely upon the rubber or adhesive plaster to hold the parts in apposition while the healing process goes on; but after the pins and sutures have been removed, in order to prevent too much tension on the newly formed tissue, I am in the habit of holding the parts well in apposition by placing narrow strips of plaster across from ear to ear. These hold the cheeks quiet and restrain the movements of the lips. Mr. Mason speaks of the use of collodion over pins and sutures. After the operation the child should be kept quiet by the use of anodynes, if necessary.

Fig. 2984.—Mumford's Sutures for Harelip; showing the final superficial stitches in place. (Mumford, Practice of Surgery. W. B. Saunders Co.)

If much blood has been swallowed we should consider the benefit to be derived from mild lavage. All up-to-date methods of infant feeding must be employed. The care of the mouth after each feeding by the use of mild antiseptic washes must not be neglected. In some cases immediately following operation the little one may require some form of stimulant. Warmth to the body is of service. Infusion is seldom called for.[7] The child should be fed first with a spoon, and, when all is going well, after a few hours, or perhaps one, two, or three days, should be allowed to nurse or take the bottle. Crying should be prevented as far as possible, and yet it is surprising to note how little harm it does. The bowels require care. Laxatives like tasteless castor oil, olive oil, or other preparations are of service.

It is clear that no one special kind of operation can be made to apply to every variety of harelip. I would say to the young surgeon who with due respect to his conscience considers carefully the operation he is about to select for these cases, that there has never occurred a period when the subject has been so well thought out, and for him to select that method of operating which he understands best. Too many operators look upon the operation as hardly worthy of much anxiety. Bearing on this point reference may be made to a valuable paper by James E. Thompson[8] of Galveston. Fortunately, we have a choice among numerous modes of procedure which practice has demonstrated to be successful. In the operation

Fig. 2985.—Malgaigne's Operation.

known as Malgaigne's, the incision is commenced at the superior part of the lip, and performed from above downward (Fig. 2985, left side, *b*, *b′*). Scissors are used as in ordinary operations, except that, when the operator has reached the lowest point possible without detaching the cut piece, he stops (Fig. 2985, left side, *a*, *a′*). The other side of the labial fissure is treated in the same way. There are then two small flaps each one of which adheres to the lip by a pedicle. After having reunited, by the aid of pins, the two margins of the cleft in their whole extent, except toward their free border (that is, toward the bottom), the surgeon should bring these flaps from above downward and should approximate them face to face (Fig. 2985, right side, *b*, *b′*). The point now is to adjust these flaps (partly by shortening them) in such a manner as to prevent the later development of a furrow. This result, which is so commonly dreaded by surgeons, may be prevented, at this stage of the operation, by preserving a piece varying in size according to the extent of the vacuum to be filled (Fig. 2985, right side, *a*, *a′*). Union is afterward affected by approximating the parts with one or two interrupted sutures or with a fine harelip pin. If care is taken to place these uniting agents very near the free margin of the lip, the cicatrices will scarcely be visible.

Fig. 2986.—Mirault's Operation.

M. Mirault, of Angers, employed one flap only. A flap is taken from above downward, but is left attached to the prolabium (Fig. 2986, left side, *a*); on the other side of the cleft the margin is completely removed (Fig. 2986, left side, *b*). The flap, *a*, is now turned down, and from being perpendicular, it becomes horizontal, and forms the margin of the lip (Fig. 2986, right side, *a* and *b*).

For double harelip Sédillot suggested a cheiloplastic operation. The sides of the central tubercles being pared, a flap of soft tissue is taken from each side, as shown in Fig. 2987. The flaps, *a*, *a*, are brought down to form the red margin of the lip, and the raw surfaces, *b*, *b*, then come in contact with the raw surfaces on the sides of the central tubercle, *b′*, *b′*.

A method which I consider worthy of careful study is that offered by the late Dr. A. M. Phelps, in a paper read before the Medical Society of the State of New York, February, 1885, presenting an operation for single harelip which contains some original and striking features.

The steps of the operation are these: "After first passing a loop through each angle of the lip for the forefinger of the left hand to hold the parts perfectly, with a pair of curved scissors separate the lip from its attachment to the jaw sufficiently to freely relieve the nostril and make all parts easily movable. The mucous membrane should be freely divided in both

Fig. 2987.—Sédillot's Operation.

directions. With an ordinary cataract knife, or a slender, sharp tenotome, puncture the lip at 1 (Fig. 2988), following the dotted lines describing a curve to 2, and from thence to 3. Withdraw the knife after going freely through each nostril at 3, and with a scalpel cut from 3 to 4 through the entire thickness of the lip. The pieces *B* and *B*, will now turn downward, leaving the V-shaped piece as seen in Fig. 2989.

"Now introduce the silk sutures as shown in Fig. 2989, after which cut away the pieces *B* and *B*, and the result will be shown in Fig. 2990. Before cutting away the pieces *B* and *B*, pull the lip up with them and stitch the mucous membrane together with catgut as farunderneath as possible. Enough tissue should be left in the median line to compensate for retraction. The temptation is to cut the pieces *B* and *B* too short. It is better to cut them long, and, if necessary, trim them a little.

"The following are a few rules which it is well to observe:

"1. Select only those cases in which one-fourth of the lip, at least, remains between the fissure and the corner of the mouth.

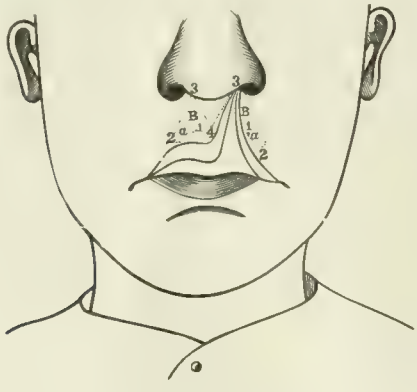

Fig. 2988

"2. Each curved incision, 1, 2, and 3 (Fig. 2988), should be an equal distance from each corner of the mouth. The curves should be similar, and both should enter the nostril at the same point on each side. On the normal side the incision should enter the nostril near the columna, and but little or none of the nostril be cut away. When the deformed nostril is drawn to a normal position the incisions will then correspond. Fig. 2988 will convey the idea.

"3. The incisions from 3 to 4, making the V, should extend to fully one-half the breadth of the lip. If the V is made too short, difficulty will be experienced in getting the lip together. This would necessitate a more extensive division of the mucous membrane, or possibly the addition of transverse incisions extending outward into the cheeks under the corners of the nose.

"A fatal mistake would be to get the center piece too long, as it would make a deformity. Cut it away to just the length to admit of the lip being stitched together, varying it according to the tension in each

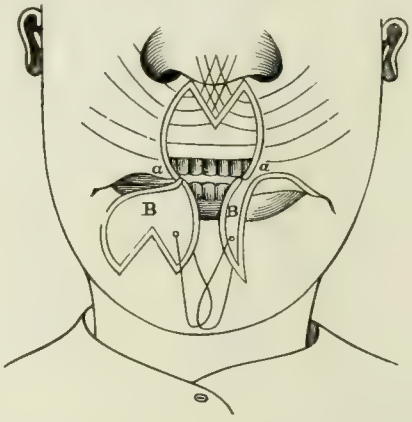

Fig. 2989.

case, *making it as short as possible.* It would be much better to make the transverse incisions to relieve tension than to leave it too long, should a case not suitable for the operation be selected.

"The steps as followed in single harelip should also be followed in double, using the double curved incisions already described.

"The advantage of the double curved incision is this: When the pieces *B* and *B*, Fig. 2988, are turned downward, the curve at *a*, *a*, becomes straight, and when joined to its fellow of the opposite side, adds just so much to the width of the lip, at a point where it is desired, as the distance is from 1 to 2, Fig. 2988. The widening of the lip at this point, and the curving downward of he white line above the vermilion border

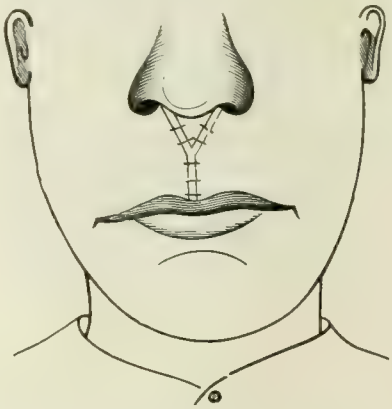

Fig. 2990.

of the lip into the point,is what lends the artistic appearance to the lip." An artistic lip and a scar in the median line are the strong points which characterize this operation.

Dr. M. H. Collis of Dublin says (Mason[3]): "I never throw away a particle of the parings. My incisions are made so as to make every fragment of them useful. On one side they are preserved to make the lip thick, and on the other to increase its depth. The method is somewhat complex, but a reference to

the accompanying figures will make it intelligible (Fig. 2994). When dealing with single harelip, I take the larger portion, that which includes the middle bit, and pare it freely from the nostril round the margin from *a* to *b*, until the point of the knife comes opposite the frenum. The incision goes through all the tissues of the lip *except* the mucous membrane. It follows the curved line of the margin of the fissure, and leaves a

Fig. 2991.—Diagram Showing the Operation for Double Harelip. The mucous borders of the gap are excised and united in a Y shape. The point of the central tab of skin does not reach to the newly formed mucous border when *A* and *A'* are approximated. (Stone, Am. Practice of Surgery, Vol. V.)

long wound, which is curved toward the fissure. The flap is left loose and attached only by mucous membrane. On the other or smaller side of the lip, where we generally find the tissues thin, especially as we approach the nostril, the treatment is quite different. I transfix the lip at *d*, close to the nostril, and carrying the knife along parallel to the margin as far as *f*, I detach a moderately broad flap, which I leave adherent above to the ala nasi, and below to the free margin of the lip, well beyond or external to the rounded angle at the fissure. This flap, which (unlike the one at the opposite side) comprises *all* the tissues of the lip, is now divided into two at its center (*c*, *e*). I thus get two loose flaps, a superior (*c*, *d*), attached to the ala nasi, and an inferior (*e*, *f*), hanging on to the free margin of the lip. The loose end of the

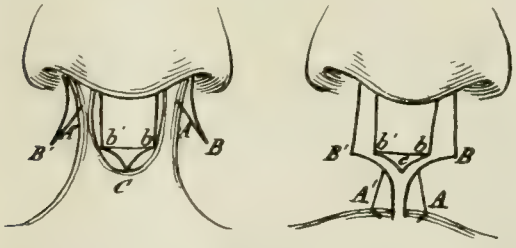

Fig. 2992.—Diagrams Showing the Operation for Double Harelip. The incisions on the sides of the median tab (to *B* and *B'*) must be equal and of the same length as the incisions made into each side of the lip (to *B* and *B'*). These latter incisions must end at points one-half as far from the mucous border as the median tab is wide: that is, the distances from *B* to the mucous border and from *B'* to the mucous border must, when added together, equal the distance from *b* to *b'*. In order to secure accurate apposition of the three flaps at the point *C* two alternatives are possible. Either the incision between *b* and *b'* may be made straight, or else it may be curved down, in two symmetrical halves, to a point at C. If the lower end of the tab is cut straight off, the lateral flaps must be trimmed squarely by the cuts *A* and *A'*. Their ends thus are approximated squarely, and the line of union is that of a letter T. If the lower end of the median tab is cut down to a point at the middle, the lateral flaps may be drawn down in a curve and united below the median point, thus making the line of union have a Y shape. (Stone, Am. Practice of Surgery, Vol. V.)

upper flap is turned up so that its raw surface faces the wound in the opposite side of the fissure, and the lower end of the lower flap is similarly turned down. The point *c* is brought up to *a*, and fastened there. The point *e* is brought down to *b*, and fastened there. I have thus got on the small side of the lip a wound as extensive as that on the larger side. The upper flap completes the outline of the nostril. The lower one supplements the outline of the free margin of the lip. I thus get a lip nearly double in depth any which I could possibly have got by the ordinary incisions."

Mr. Thomas Smith recommends an operation which is useful in suitable cases of double harelip. According to his plan the lateral sides are to be pared in the

Fig. 2993.—Diagrams Showing the Operation of Hagedorn for Double Harelip. The borders of the central tab are refreshed; the median part of the lower border being made as pointed as possible. The mucous borders of the lip on both sides of the defect are excised at the upper part only (to *D'*). Secondary incisions (*B' A'*) are then made downward and outward into the lips on each side of the defect. These incisions should be parallel with the curving border between *D'* and *C'*. The distance from the nostril to *A'* should equal the height of the side of the median tab (to *A*) The length of the cut *B'A'* should be one-half the width of the lower border of the median tab *B A*. (Stone, Am. Practice of Surgery, Vol. V.)

manner shown in Fig. 2995, *a*, *a'*, and two flaps are to be taken from the central tubercle, but are not to be detached at their lower margins. "The wound is closed by drawing down the flaps from the side of the central tubercle, and attaching them to the raw surface on the lower margin of the lip."

The condition of the infant before operating should be as good as possible. There should be no unfortunate surroundings, especially as regards diphtheria and

Fig. 2994.—Collis' Operation.

allied conditions, nor should the operation be done in hot weather, or at any time in the year when epidemics of any kind peculiar to children are prevailing.

As a general rule, one operation is all that is needed, but sometimes failure occurs, and in this we ought not to be discouraged, but, as soon as the child has sufficiently improved, we should try again. Among the more recent contributions I am pleased to refer to those of F. W. Goyer[9] and of Raymond C. Turck.[10]

Fig. 2995.—T. Smith's Operation.

Regarding Hainsby's truss, I have had but little experience in its use, and must say that it requires great care, and is apt to annoy the child.

As to a second operation, years after the first, to relieve an unsightly scar or depression in the vermilion border of the lip, I am much in favor of its performance especially in females. Albert Vander Veer.

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Harlan, George C.—Born in Philadelphia on January 28, 1835. He studied medicine at the University of Pennsylvania, and received his doctor's degree from that institution in 1858. During the greater part of his professional life he devoted himself chiefly to eye surgery, and he attained such eminence in this department of surgical practice that he was universally acknowledged by his confrères to be one of the leading ophthalmologists of Philadelphia. He died September 25, 1909.

Of his published writings the following deserve to be specially mentioned: "Simulated Amaurosis," "Neuroparalytic Ophthalmia," "Pulsating Exophthalmus," "Hysterical Affections of the Eye," "Albuminuric Retinitis," "Strychnine in Atrophy of the Optic Nerve," "Hemiopia and Decussation of the Optic Nerves," and "Surgical Diseases of the Eye," in American Practice of Surgery, New York, 1905–1911.

A. H. B.

Harris Springs.—Laurens County, South Carolina.

Post-office.—Harris Springs. The hotel is not in operation at the present time but plans are under way whereby new buildings will be erected and the place improved in general.

Access.—Viâ Seaboard Air Line Railroad to Cross Hill; thence about three miles to springs. Or, viâ Charleston and Western Carolina Railroad to Waterloo, and thence two miles to springs. These springs are located in a hilly country. They are two in number, known respectively as the "Lithia" and the "Sulphur" Springs. They flow about sixty gallons per hour each. The following analysis was made on April 10, 1913, by H. C. White, D. Sc., LL. D., Professor of Chemistry, University of Georgia.

Analysis.

The water is clear, colorless, and odorless, and is faintly acid in reaction.

Specific gravity (at 60° F.)	1.00138
Total solids (dried at 260° F.) per 1,000,000 water	1899.866
Loss on ignition	68.743
	1831.123

Constituents dissolved.	Parts per 1,000,000
Calcium	501.129
Potassium	4.491
Sodium	18.925
Lithium	1.850
Magnesium	11.862
Iron	2.503
Alumina	21.462
Sulphur trioxide	1012.252
Chlorine	7.114
Silica	58.900
Carbon dioxide in bicarbonates	80.499
Nitrogen—in free ammonia	None.
in albuminoid ammonia	0.025
in nitrites	None.
in nitrates	0.010

Probable Combination of Ingredients.

Solids dissolved.	Grains per U. S. gallon.	Grains per Imp. gallon.
Calcium sulphate	99.435	119.318
Potassium sulphate	0.582	0.697
Sodium sulphate	0.561	0.672
Sodium chloride	0.684	0.815
Sodium bicarbonate	2.382	2.846
Lithium bicarbonate	1.052	1.258
Magnesium bicarbonate	4.210	5.032
Iron bicarbonate	0.465	0.550
Alumina	1.252	1.495
Silica	3.436	4.110
	114.059	136.793

No evidence of the presence of helium was detected. The water exhibited no radioactivity.

Bacteriological Analysis.

Total bacteria, per 1 c.c.	60
Colon bacillus, per 1 c.c.	0
Colon bacillus, per 10 c.c.	0

Compared with the analysis made in previous years this water exhibits remarkable constancy and uniformity in composition. Doubtless it preserves its attested medicinal qualities.

The combination of mineral ingredients shown in this analysis would suggest a very useful water. It is highly effervescent and agreeable to the taste. It is, therefore, useful for the table, and mixes well with wines. It is a speedy corrector of acidity of the stomach. It is said that the water causes a notable reduction of sugar in the urine in diabetes mellitus. It also overcomes constipation, and is useful in rheumatism, uric-acid gravel, calculi, diseases of the stomach, bowels, kidneys, bladder, liver, and bile-ducts, and in the diseases of women.

Emma E. Walker.

Harrogate.—Harrogate is situated in Yorkshire in the central portion of England, midway between the Irish Sea and the German Ocean, four and one-half hours by rail from London. Its reputation depends not only upon its waters but as well upon its climate, which is dry, invigorating, and with an atmosphere of remarkable purity. It has an elevation of 260 to 600 feet above sea-level. The town consists of "Low" and "High" Harrogate, High Harrogate possessing the more bracing climate, while Low Harrogate is more sheltered and enjoys a reputation as a winter resort. There are fewer rainy days, it is said, than at most of the other English health resorts. The season is from May to September, though the spa is open at other times of the year.

There are about eighty different cold mineral springs at Harrogate, most of them containing sulphur in the form of sulphuretted hydrogen and sulphide of sodium, varying greatly in strength and proportion of the constituents. The most popular spring and the one generally used for drinking is the "Old Sulphur Spring" in the Royal Pump Room, which contains about 0.07 of sodium sulphide and thirty-seven volumes of sulphuretted hydrogen per liter; it also contains 12.7 of common salt and 0.09 of barium chloride, which latter substance is said to act as a heart tonic and to obviate any depressing effects of the sulphur. The "Montpellier" is the strongest in sulphur, estimated to contain 0.2 per liter of sodium sulphide with no sulphuretted hydrogen. The Starbeck wells, on the contrary, are weak in sulphur and are used for baths.

There are also iron springs, and of these the famous "Kissingen Well" contains 0.13 of carbonate of iron, 10.0 of sodium chloride, and 1.2 calcium chloride per liter, and the "chloride-of-iron well" contains 0.19 of chloride of iron, 0.16 of carbonate of iron, 2.5 of chloride of sodium, and 0.07 of chloride of barium per liter.

There is also the sulphate-of-iron water from the so-called "alum well" in the "bog field," containing ferrous sulphate, ferric sulphate, aluminum sulphate, calcium sulphate, and magnesium sulphate, about 1.0 per liter of each.

The waters of Harrogate are applicable to about the same class of cases as are treated at Homburg and Kissingen, although the waters of these two latter spas contain no sulphur, and Kissingen contains no iron. Chlorosis, anemia, hepatic disorders, lead and mercurial poisoning, chronic dyspepsia, constipation, obesity, certain skin diseases, functional uterine disorders, scrofula, chronic gouty and rheumatic conditions, bronchitis and high blood pressure, are all said to be benefited by the use of these waters. It is well to remember that the climate, regular mode of living, freedom from care, and the general simplicity of life add much to the effect of the waters, and this is true of all water cures.

The sulphur waters, of which the "Old Sulphur Spring" stands first in importance—the chlorides it contains giving it a special therapeutic value—are employed both for drinking and in baths, particularly for drinking, and are most useful in functional hepatic disorders, digestive disturbances, constipation, etc., gout, rheumatism, chronic lead poisoning, and externally in eczema and psoriasis. The chalybeate waters are employed in anemia, albuminuria, convalescence from prolonged or severe illness, scrofula, and also in chronic rheumatic arthritis.

The contraindications to the use of these waters are organic diseases of the heart, blood-vessels, liver, and kidneys, and in cases of asthma, insomnia, and neurotic conditions generally.

The bath establishments are modern and complete. The Royal Baths, called "one of the sights of Europe" are furnished with all modern appliances and are capable of giving 1,500 treatments a day; there are also the Victoria and Starbeck baths. There are special attendants for administering the "Aix douche" as is done at Aix-les-Bains, which are much employed in chronic gouty and rheumatic cases. Almost every other kind of bath known, can be obtained here.

The accommodations are good and abundant. The hotels and residences are built around an open common of two hundred acres; the sanitary conditions are excellent, and there is an abundant supply of pure, soft water. The amusements are music, tennis, golf, cycling, cricket, and hunting. The scenery about Harrogate is very attractive, affording many interesting excursions. EDWARD O. OTIS.

Hart, Ernest Abraham.—Born in London, England, on June 26, 1835. He was a pupil of St. George's and St. Mary's Hospitals, and was subsequently chosen Anatomical Prosector at the former of these institutions and Instructor in Ophthalmology and Otology at the latter. In 1856 he was elected a Member of the Royal College of Surgeons. In 1893 the honorary title of Doctor of Common Laws was bestowed upon him by the University of Durham. For several years he was Associate Editor of *The Lancet*. Then, in 1866, the Council of the British Medical Association elected him Editor-in-Chief of the *British Medical Journal*—a position which he filled up to the time of his death, January 7, 1898.

Hart made a large number of contributions to medical literature, not a few of his published writings relating to public hygiene and to the general interests of the Medical Profession. In 1873 he began the publication of the *London Medical Recorder* and one year later he issued the first number of the *Sanitary Record*. "The record of his public work," says the Encyclopædia Britannica (11th edition), "covers nearly the whole field of sanitary legislation during the last thirty years of his life. He had a hand in the amendments of the Public Health and of the Medical Acts; in the measures relating to notification of infectious disease, to vaccination, to the registration of plumbers; in the improvement of factory legislation; in the remedy of legitimate grievances of Army and Navy medical officers; in the removal of abuses and deficiencies in crowded barrack schools; in denouncing the sanitary shortcomings of the Indian government, particularly in regard to the prevention of cholera." A. H. B.

Hartshorne, Joseph.—Born in Alexandria, Va., December 12, 1779. He received his collegiate education at the Alexandria Academy and entered his father's counting-house for a short period. Soon, however, his attention was drawn to the study of medicine, and he became a pupil of Dr. James Kraik, of Washington. He studied with him for two years, and in July, 1801, received the appointment of resident apprentice and apothecary in the Pennsylvania Hospital of Philadelphia and served in that capacity for five years. Soen after he received his hospital appointment he entered the medical class of the University of Pennsylvania, at twenty-two years of age. He devoted the next seven years to study and work in both University and Hospital and received his degree in medicine in 1808. The certificate presented to him upon the termination of his hospital service, after expressing approval of his conduct while in service, further showed appreciation by the following extract: "In the practical duties of his profession, he has displayed, under the inspection and advice of six of the most eminent physicians of Philadelphia, a skill seldom to be met with in practitioners of his years. From a well-founded confidence in his abilities and fitness for the charge, the care of the out-door patients has been intrusted to him exclusively during the last year of his meritorious services; and the uncommon success with which his practice was marked, left us no cause either to regret or to diminish our confidence in him." After graduation he made two voyages to Batavia in an East India merchantman, gaining much valuable information and experience of the fevers and intestinal affections prevalent in the East. On his return he settled in Philadelphia and entered in partnership with an old friend as a druggist. After two or three year's experience in combining medicine with pharmacy, he gave up the latter and practised medicine exclusively. In 1815, he was unanimously elected one of the surgeons of the Pennsylvania Hospital, but in 1821 on account of the demands of a constantly increasing practice, he resigned this appointment. He was a member of the Philadelphia Medical Society, of the American Philosophical Society, and of the College of Physicians of Philadelphia. He died at Brandywine Springs, near Wilmington, Del., August 20, 1850.

Hartshorne, through his strength of character, devotion to study and work and brilliancy of mind, may well be classed among the eminent physicians of his time. Rush, Wistar, Physick, and Barton were his preceptors and his associates. He wrote very little and the only book with which his name is connected is an American edition of "Bover's Treatise on Diseases of the Bones." While Resident in the Pennsylvania Hospital he compiled the first regular alphabetical catalogue prepared for publication at the hospital, and for which he received a special vote of thanks from the hospital. During the same period of his life he translated "Desault's Clinical Lectures on Fractures." In 1805 he wrote an article "On the Effects Produced by Air on Living Animals."

E. L. J.

Harvey, William.—Born at Folkstone, County of Kent, England, April 1, 1578. After completing his medical studies in his native country, he visited France, Germany, and Italy for the purpose of gaining still further knowledge. Attracted to Padua by

the great reputation of Fabricius of Aquapendente, he decided to remain for a considerable length of time in that city, under the instruction of the celebrated anatomist. On April 25, 1602, he received the degree of M. D. Upon his return to England he took up his abode in London, and began the practice of his profession. In 1604 he received the appointment of Physician to St. Bartholomew's Hospital, and in 1623 the King chose him one of his regular medical attendants. In 1613, in the course of his instruction to medical students, Harvey mentioned for the first

Fig. 2996.—William Harvey.

time his views in regard to the circulation of the blood; but it was not until 1628 that he published a formal exposition of the new doctrine. Notwithstanding the facts that he stood high in the esteem of his professional brethren, and that they received his theory of the circulation with apparent favor, Harvey soon afterward, in a letter which is still in existence, complained to a friend that his practice had fallen off very noticeably since the publication of the treatise in question. This experience illustrates how strong were the prejudices which people at that period entertained against anybody who introduced new ideas. The King, on the other hand, showed a high appreciation of the value of Harvey's discovery and aided him materially in a variety of ways. Among other things, he employed him to accompany the Duke of Lennox (James Stuart, afterward Duke of Richmond) on his travels, and, at a still later period, attached him to his own suite. He also appointed him Warden or President of Merton College, Oxford. Harvey's death occurred June 3, 1657.

Harvey's principal writings are to be found in the fine quarto edition of his works published by the Royal College of Physicians in 1766. They include the treatises on the circulation of the blood, on generation and on respiration, and a report of the postmortem examination which he made on the body of Thomas Parr, who was reputed to have attained the age of 152 years. A. H. B.

Hassall, Arthur Hill.—Born at Teddington, near London, September 13, 1817. He studied medicine in Dublin, under Sir James Murray, was appointed Physician to the Royal Free Hospital in London, and received his degree of Doctor of Medicine, from the University of London, in 1851. He practiced his profession at first in London, then in the Isle of Wight, and also for some time in San Remo, on the Mediterranean Coast. He was the founder and the consulting physician of the Royal National Hospital for Consumption and Diseases of the Chest at Ventnor, on the Isle of Wight—an institution capable of accommodating 130 patients, each one of whom is entitled to have a separate sleeping room. He died April 10, 1894.

Of Hassall's numerous published writings, which relate to a great variety of topics, only the following few may here be enumerated: "The Microscopic Anatomy of the Human Body in Health and Disease," London, 1846 (New York, 1851; 1855; 1869); "Foods Water, and Air in Relation to the Public Health," 1871–1874; "Food; its Adulterations and the Method, for their Detection," 1876; and "The Urine in Health and Disease," 2nd edition, 1863. A. H. B.

Hastings and St. Leonard's.—These two places, virtually one town of about 66,000 inhabitants, are situated sixty-two miles southeast of London on the coast. Their claim as a health resort is based upon the mildness of their winter climate, which renders them a comparatively favorable residence for those of feeble vitality, and for sufferers from chronic bronchitis or other form of "mucous membrane delicacy."

The front of the town looks toward the South and the open sea, and an esplanade three miles in length extends along the shore. In the rear are downs which afford shelter from the northerly winds. The country about is picturesque, affording many attractive excursions; there are also various public parks and gardens. Round about are hills broken by numerous valleys, thus offering some variety of climate. The soil is more or less sandy, through which the rain water rapidly escapes.

The mean average temperature for the four seasons is as follows: Spring, 47.1° F.; summer, 60.3° F.; autumn, 51.5 F.; winter, 40.1° F.; for the year 49.9° F.

The mean daily range is 10.4°.

The day temperature averages 54.6° F., and the night temperature 44.2° F. The mean relative humidity is eighty-four per cent. for the year. The daily range of temperature is 10.7° F.

The most prevalent winds are from the west and southwest. The average rainfall is 29.95 inches per annum, falling on an average of one hundred and eighty-three days.

The mean amount of bright sunshine (average for eight years) is 1,699.9 hours, or 4.6 hours per day; the least amount is during the winter months.

Sea fogs are not infrequent but do not last long; land fogs are rare. The sea front enjoys the mildest winter climate, on account of its southerly exposure and shelter from the northerly winds; it is therefore the place of residence for the invalid, in winter. The mildness of the winter climate is indicated by the various plants and shrubs which flourish during that season, such as the arbutus, primrose, hepatica, violet, and hydrangea. The drainage is good, and the water supply abundant and of good quality. Along the esplanade before mentioned are hotels, lodging houses, private residences, and shops. In the spring the east winds begin to blow, and these are often "searching," but are somewhat mitigated by the bright sunshine.

Mildness and equability, with protection from northerly winds and a comparatively large amount of sunshine, are the characteristics of this climate from which these towns have derived their popularity as a winter health resort.

The southwest wind which is the prevalent one, except in the spring, is said to render the climate somewhat relaxing.

The sea bathing is good and there is a swimming pool 180 feet long and forty feet wide in which the water is tepid. There are also Turkish, Russian, and medicated baths.

Patients affected with various maladies frequent this resort; catarrhal affections of the throat and lungs, chronic diseases of the heart and kidney, neurasthenia, insomnia, surgical tuberculosis in children, chronic bronchitis, convalescence from acute diseases, scrofula, and anemia are the principal diseases and conditions which are benefited by this climate. Chronic rheumatism, neuralgia, and asthma in children also often receive much benefit in this air.

"The long, sunny parade, sheltered from northerly winds, offers facilities for outdoor exercise. Many persons have found that they can pass the winter at least as well here as in Southern Continental health resorts. This is especially the case when the patients can be induced to admit fresh air into their rooms freely both day and night. The 'fresh-air cure' is more practicable in a South of England seaside resort than inland, where the night air is damper and more chilly." ("Climates and Baths of Great Britain," 1895.)

"The contraindications, beyond those which apply to marine stations in general, are singularly few."

EDWARD O. OTIS.

Hastings, Sir Charles.—The founder of the British Medical Association was born at Ludlow in Shropshire, England, January, 1794. He began his medical education under private tuition when but sixteen years of age and after two years was appointed house-surgeon of the Worcester Infirmary. Three years later he entered the University of Edinburgh from which he was graduated in 1818, settling then in practice in Worcester. He was early impressed with

FIG. 2997.—Sir Charles Hastings.

the disadvantages of the isolation of the country practitioner, and to correct the evils in a measure he established a journal, *The Midland Medical and Surgical Reporter*, which was published for four years only, being discontinued to make way for the Transactions of the Provincial Medical and Surgical Association. This Association, which Hastings founded and in which he held a prominent position throughout his life, was later expanded into the British Medical Association.

It was, however, not merely as the founder of this great organization that Hastings won an enduring fame. He was a physiologist of note, having begun his researches on the nature of the circulation and the action of the blood-vessels, under the guidance of Dr. Wilson Philip, while house-surgeon of the Worcester Infirmary. It is said that he was the first student in the University of Edinburgh to use the microscope as an aid in physiological research. Upon graduation in 1818, he was offered the professorship of physiology in the University, but declined it as his ambition was to become the leader of his profession in his native county. He was also a sanitarian and early turned his attention to preventive medicine.

Hastings died after a long illness on July 30, 1866. His writings were not many, but he published a work early in his career which gave him an important place among the scientists of his day. This was entitled "A Treatise on Inflammation of the Mucous Membrane of the Lungs, to which is prefixed an experimental inquiry respecting the contractile power of the blood-vessels, and the nature of inflammation," London, 1820. This was translated into several European languages and brought him many honorary degrees from foreign universities and membership in several Continental societies. T. L. S.

Hathorn Spring.—See *Saratoga Springs*.

Havers, Clopton.—English anatomist who lived during the second half of the seventeenth century (1650–1702) and who gained considerable celebrity by his investigations into the structure of bones. The treatise on this subject is entitled "Osteologia nova, or some new observations of the bones and the parts belonging to them, with the manner of the accretion and nutrition; and a discourse of the cartilages." Ulm.; London, 1691. The terms "Haversian canals" and "Haversian system," to be found in all modern works on anatomy, combine to perpetuate the name of the subject of this brief sketch. A. H. B.

Haw, Black.—See *Viburnum Prunifolium*.

Hawaii.—The Territory of Hawaii, United State, of America, consists of twenty islands in the mid-Pacific ocean between north latitudes 18° and 30°, and west (Greenwich) longitudes 154° and 172°. The islands comprising this territory are: Hawaii, Maui, Oahu, Kauai, Molokai, Lanai, Kahoolawe, Niihau, Molokini, Lehua, Kaula, Bird, Neckers Johnson, Laysan, Lysiauski, Ocean, Midway, French Frigate Shoal, and Pearl Reef. The eight first-named islands are inhabited permanently, and constitute the ones usually comprehended as the Hawaiian or Sandwich group. (Three of the eight, Niihau, Lanai, and Kahoolawe, are, however, nothing more than cattle ranches.) The remaining twelve are small islets, little more than rocks or coral reefs, and uninhabited except at such times as they are visited by workmen of guano companies collecting the eggs and the manure of the innumerable sea birds and turtles making these spots their homes. The areas of the eight major islands are:

	Square miles.		Square miles.
Hawaii	4,015	Molokai	310
Maui	760	Lanai	160
Oahu	600	Niihau	97
Kauai	590	Kahoolawe	69

Honolulu, the capital of the Territory, in Oahu is 2,100 miles from San Francisco, 3,810 miles from Auckland, 3,440 miles from Yokohama, 2,380 miles from Tahiti, 4,665 miles from Panama, and 4,843 miles from Manila.

History.—The islands were visited by some Spanish navigators as early as 1542, and two Spanish ships were wrecked on them probably in 1527. The actual, that is, useful, discovery of the islands was made by Captain Cook in 1778, who gave them the name of Sandwich in honor of the first lord of the British Admiralty at the time. Hawaii, the native name of the largest member of the group, has, however, been the one generally applied to the archipelago, and is now the legal name of the Territory. At the time of Cook's discovery the different islands were governed by one or more independent chiefs. Shortly therafter Kamehameha, a chief of Hawaii, subjugated the other chiefs, and established the kingdom of Hawaii, which remained with some vicissitudes an independent government till 1893. Liliuokalani, who succeeded her brother King Kalakua, in 1891, having manifested an intention to change the existing constitution, provoked a revolution, January, 1893, in which she was deposed. A provisional republic was proclaimed and negotiations were begun looking to the final annexation of the islands to the United States. A republic was formed in 1894, and negotiations continued. After some delay, caused by changes in

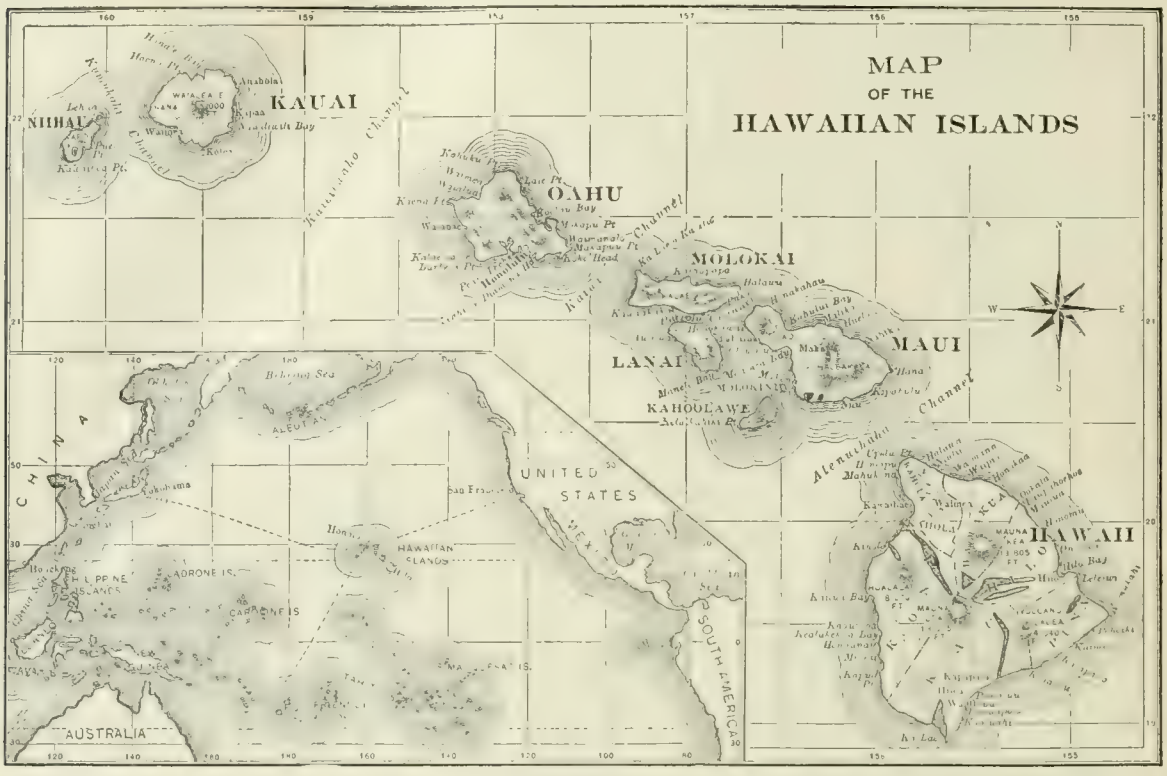

FIG. 2998.

the political ascendencies in the United States, the islands were finally admitted into the Union as the Territory of Hawaii. The annexation took place formally August 12, 1898.

Population.—Captain Cook estimated the native population as 400,000 inhabitants, an estimate undoubtedly too great. The first census, taken in 1823, showed 130,313 natives. According to the census of 1878 these had decreased to 44,088. A census of the islands in 1896 gave a total population of 109,020 inhabitants, composed as follows:

Native Hawaiians	31,019	Portuguese	15,191
Mixed Hawaiians	8,485	Americans	3,089
Japanese	24,407	All other nationalities	5,204
Chinese	21,616		

The pupulation as returned by the two decennial censuses since the admission of the Territory into the United States is given as follows:

	1910.	1900.
Native Hawaiians	26,041	29,799
Mixed Hawaiians	12,506	7,857
Japanese	79,675	61,111
Chinese	21,674	25,767
Portuguese	22,301	*
Americans	5,688	4,238
All other nationalities	24,024	25,229
Total	191,909	154,001

The population of Honolulu, the capital of the Territory, was 22,907 in 1890, 39,306 in 1900, and 52,183 in 1910.

The population of the eight major islands in 1910 was as follows:

Hawaii	52,382	Molokai	1,791
Maui	28,623	Lanai	131
Oahu	81,993	Niihau	208
Kauai	23,744	Kahoolawe	2

* Not separately returned, included in *all other* nationalities.

The present outlook is the gradual extinction of the native Hawaiian race. The decrease in native population gave great concern to the original government and strenuous efforts were made to check it, but without avail. In general appearance the natives are fine specimens of physical development; the women, however, are not fruitful, and few families are found with as many as three children. The original islanders belong to the widely scattered Malayo-Polynesian family. Although more than 3,000 miles of ocean intervene, Hawaiians and the Maoris of New Zealand can readily understand each other's speech. Cannibalism, idolatry, and human sacrifices were practised at the time of discovery, though the cannibalism was only moderate, and to some extent a part of the religion. Of the population ten years of age and over, fifty-seven per cent. were in 1910 unable to speak English. The religious adhesions of the present population are almost as diverse as the races are polyglot. The census of 1896 gave Roman Catholics 26,363, Protestants 23,773, Mormons 4,886, Buddhists, Confucians, and other Oriental sects 44,306, unknown 10,192. No later religious census appears to have been taken, but from the nationalities of the immigration of the last eighteen years, the religious affiliations of the present population may be assumed as equally diversified as in 1896. Notwithstanding the great influx of foreigners due to political changes, the condition of population offers material for serious consideration. Agriculture is the industry of the islands, and laborers are imperatively needed in agriculture. The larger part of the arable land of the archipelago is devoted to sugar production and the conditions under which this industry is practised at

present discourage a peasant proprietorship of the land. Without such proprietorship there can be little hope of a permanent population. In recent years attention has been directed to the economic value of diversification of crops—fruits especially appearing well adapted to both soil and climate. Sugar, however, remains the great industry of the islands, the value of the crop in 1912 being $49,961,536. There are at present a total of about 200 miles of railroad in operation. All the important points on the larger islands are connected by telephone or telegraph. Also the larger islands have wireless telegraph stations for intercommunication and maritime purposes. Submarine cables connect Hawaii with both shores of the Pacific. Inter-island communication is maintained by steamship lines that regularly visit all ports of consequence in the territory. Hawaii being a sort of midway house for oceanic travel, it has excellent facilities for communication with both the oriental and occidental continents. The valuation in 1900 of the imports into the United States was $20,707,903, and of the exports from the United States to the islands, $13,509,148. The corresponding values in 1912 were $55,076,165 and $23,095,878 respectively. The facilities and conveniences of living in Honolulu and Hilo, the chief towns, are the same as those in like cities of the United States. The cost of living is, since annexation, however, higher, largely due to the servant question. The Chinese constitute the chief source from which this element is drawn, and since annexation they are excluded from the islands as from all other parts of the Union.

Geography and Geology.—The Hawaiian Islands are of volcanic origin. They rise from the general level of the ocean bottom to the surface a distance of 14,000 to 19,000 feet. This rise is so abrupt that this great depth of water is found from 30 to 50 miles from shore. Above sea level the islands attain elevations that in many places rival the heights of the Alps. The coast line is in places low, in others it rises often sheer 2,000 feet. The following tabular view shows the chief elevations.

Islands.	Name of mountain peak.	Height above sea, feet.
Hawaii	Mauna Kea	13,805
Hawaii	Mauna Loa	13,675
Hawaii	Hualalai	8,275
Hawaii	Kilauea	4,040
Hawaii	Kohala mountains	5,000
Maui	Haleakala	10,032
Maui	Eeka	5,820
Kahoolawe	(Highsst point)	1,130
Lanai	(Highest point)	3,000
Molokai	(Highest point)	3,500
Oahu	Kaula	4,060
Kauai	Waialeale	5,000

Geologically, Hawaii is the most recent and Kauai the eldest of the group; the islands increasing in age from the southeast to the northwest. Kauai from its greater age has the best weathered soil, and by its inhabitants is proudly called the garden island. The soil of the islands is weathered lava. It is extremely porous. Two general classes are recognized, dark red soil, from simple weathering, and light red and yellow soils from weathering plus the action of imprisoned sulphurous and other gases. The dark red is the better and more durable agricultural soil. The light red and yellow soils require careful cultivation. But few minerals are found. Sulphur, pyrites, copperas, sal ammoniac, common salt, and a few others are the chief ones. Hawaii has the only active volcano, the world-renowned crater Kilauea. The summit of Mauna Loa has a crater, Mokuaweoweo, occasionally active. From Hilo, the chief town of the island, a good road, thirty miles in extent, runs to Kilauea. Haleakala, in Maui, is an extinct crater, the largest known in the world. Although more than 10,000 feet high, so gentle is the slope that it can be ascended to the top on horseback. Most of the other mountains of the islands are more or less easily rising slopes, and mountaineering is not arduous.

Flora and Fauna. The mere enumeration of the varieties of flora on the islands would exceed the length of this article. Hillebrand, in his "Flora of the Hawaiian Islands," names 999 species and 365 genera, and many others have been introduced since his book was published. "The variation in the climatic conditions due to altitude and location . . . together with the arable soil at all altitudes, justify the belief and warrant the assertion that almost every tropical and temperate plant can somewhere be grown successfully on this island" [Hawaii] (Dr. W. C. Stubbs, "Report on the Agricultural Resources, etc., Hawaii," Washington, 1901). Over seventy species of birds, mostly water fowls, have been enumerated. Captain Cook found hogs, dogs, domestic hens, and rats on the island, also a day-flying bat. Cattle, goats, and hogs, escaped from domestication, run wild (goats were introduced by Vancouver in 1792) and have damaged the forests incalculably.

Climate.—The Hawaiian Islands are climatically within the sea level isotherms of 70° and 75° F. The average sea-level temperature of the group is 4° to 6° lower than the calculated average of the latitude (see table, article *Climate*). The distinguishing characteristic of Hawaiian climate, compared with that of other tropic islands, is the combination, in its temperature, of mildness and equability. There are many other tropic islands that have great or even greater equability of temperature, but they lack in greater or lesser degree the other element of mildness so pronounced in the perpetual, pleasant summer of the Hawaiian archipelago. The following table shows the temperature of Honolulu compared with that of some other insular localities in or near the tropics.

	Average Temperature of—		
	Year.	Warmest month.	Coldest month.
Honolulu	74° F.	78° F.	70° F.
Praia, Cape Verde Islands	76	80	72
Las Palmas, Canary Islands	70	75	65
Bermuda	70	80	63
Nassau, W. I.	77	82	72
San Juan, Porto Rico	81	84	76
Saint Helena	71	76	68
Mauritius	74	79	69
Tahiti	77	80	74
Levuka, Fiji Islands	78	82	75
Réunion	74	79	70

The average temperature and rainfall at Honolulu are:

	Temperature.	Rainfall (inches).
January	70	3.5
February	71	6.0
March	71	3.3
April	73	3.0
May	74	3.0
June	76	1.6
July	77	1.8
August	78	2.0
September	78	2.0
October	76	2.5
November	74	5.5
December	72	4.7
Year	74	38.4

The temperature seldom rises above 90° F. The average daily difference between the highest and lowest temperatures at or near sea level is from 10° to 14° according to the season of the year. The temperature of a particular locality will depend upon the elevation of the place and its exposure. Owing to the small land areas of the different islands the rate of decrease in temperature due to altitude is practically that found in ascending in the free air, namely 1° F. for every 300 feet vertical ascent. The altitudes of some of the mountain peaks of the islands place their summits within the limits of perpetual snow. The crests of Mauna Kea and Mauna Loa are seldom entirely free of snow. The rainfall of the islands follows the regimen of tropical islands similarly situated with respect to the prevailing winds. The key to the rainfall is altitude and the prevailing winds of the region and the season. The rainfall is plentiful wherever the land rises sufficiently to be a barrier to the winds of the region. At sea level the rainfall is relatively small, but it increases rapidly with elevation up to 6,000 feet, and then decreases. From the orography of the islands the greatest variety of rainfall distribution is observed. On Hawaii the average annual rainfall varies from 136 inches at Hilo on the east coast to less than 30 inches on the west coast. On Oahu a more striking difference is observed. At Honolulu, 50 feet above sea level, the average annual fall is 38 inches, while about 15 miles east, at Luakaha, 850 feet above the sea, the average is 132 inches, and less than 25 miles west, in a sheltered valley, the rainfall is only 15 inches. Even on the same plantation, the rainfall on one part will be abundant for the most luxuriant tropical growth and on the other part irrigation will be necessary to grow an ordinary crop. The porosity of the soil is, as already stated, great, so that notwithstanding the torrential downpours that occur on the elevated lands, the soil remains free from dampness. The water runs through it with great rapidity. The average relative humidity of the islands is about seventy-five per cent. of saturation, varying somewhat with the direction of the wind. It is greater with southerly and less with northerly winds. The prevailing winds of the archipelago are the northeast trades. For nine months, March to November, they blow with almost unfailing regularity. During the other three months the islands are more or less under the influence of the southwest antitrades. These antitrades are the disagreeable winds of the islands. It is only during their prevalence that the sultriness and oppressiveness of the tropics become manifest.

Health.—Statistics as to the prevailing diseases of the islands are not plentiful. The general death rate is given as 16.29 per thousand for the year 1908. Leprosy, an imported disease, is endemic among the natives. Great care has been taken to prevent its ravages and stamp it out. The government years ago established a leper colony on the high table-land of Molokai, and hither all afflicted are sent and carefully cared for. However, segregation has not proved as satisfactory as was expected.

Among the causes of death phthisis claims a considerable number—so large a number indeed that legislative action has been taken to prevent its ravages.

W. F. R. Phillips.

Hay Fever—History.—Hay fever is a term that perhaps was first applied by John Bostock, of England, in 1819, in describing a disorder characterized chiefly by attacks of sneezing, nasal stuffiness and profuse watery discharge, lasting several weeks and recurring periodically every year at about the same time.

A knowledge or at least a description of this disorder dates back to a comparatively recent period. If the earlier followers of medicine recognized such a group of symptoms as a distinct disorder, they have given us no exact record of their knowledge, although the similarity between some of the conditions described by them as humors and head flux are so striking that one is ready to believe the disorder must have been in existence in the early history of medicine.

With the light of our present knowledge, it can be seen that considerable confusion existed in the minds of the earlier writers as to the cause of this disorder. Benningerus, in 1673, appears to have given reference to such an affection, and Heberden, in 1773, also seemed to have given it particular notice. It is less than one hundred years ago since Bostock gave the first precise description of what has ever since that time been known as hay fever. The disorder described by him represents the variety known to-day as the European type. But we in America have a type of our own, although similar to the European type in many respects. If the knowledge of this disorder dates back to but a matter of about one hundred years, it would seem that its prevalence then was comparatively slight when compared with the great number of cases in existence to-day. In America alone there are hundreds of thousands who annually suffer at the shrine of this disorder. Pilgrimages are made by thousands seeking relief from their torment in suitable altitudes and latitudes. A Hay Fever Association has even been formed, whose large membership of fellow sufferers, organized partly for the purpose of studying their disease, meet annually in the New England States. Similar organizations exist in other countries.

Just why the great prevalence of this disorder obtains almost everywhere to-day as compared with its infrequent occurrence only a few hundred years ago may be difficult to answer satisfactorily. Perhaps, as we study the etiology and pathogenesis, as taken up later on, a good reason may present itself. Perhaps the disorder was in reality quite prevalent many centuries ago, but our honorable confrères may not have recognized it—at least, not as we do to-day, and hence the great discrepancy in the frequency of the disorder may be more apparent than real.

There has been considerable difference of opinion as to what name this disorder should be known by. The term hay fever has been the most popular one, and as such is perhaps best known the world over, although many localities still adhere to their own peculiar ideas on the subject, and accordingly many other names exist by which this condition is known.

In 1886 Beschorner collected something like fifty different names from the English, German, and French literature designating this disorder.

On account of its occurring in the spring or fall of the year, it is frequently referred to as spring or fall catarrh. But these terms do not sufficiently describe that variety occurring in between these year periods, as in summer or winter, or the perennial variety. With the idea that certain irritating substances in the air were factors in causing the symptoms, such names as rose fever, hay fever, dust fever, ragweed fever, grass fever, peach fever, etc., have been applied. Just why the word "fever" was incorporated is not comprehensible. There is no actual fever present. This disease is not one of an inflammatory character; that is to say, so far as we know to-day its pathogenesis does not present the characteristics of inflammation that is caused by microbic infection or trauma. Therefore, the use of the word fever seems misapplied and leads to erroneous understanding. Perhaps, for the same reason, it may be said that the word rhinitis, another word often used with reference to this disorder, is equally inappropriate. But here we may be more liberal in the interpretation of the word, because there is most often present a chronic rhinitis, either of the simple, hypertrophic or hyperplastic variety. I have never seen the disease occur in the presence of an atrophic rhinitis.

Because of its rather obscure origin or its resemblance to the reflex manifestations that result from physiological disturbances of the mucous membrane of the nose, such as sneezing, congestion, and watery discharge, it has received such appellations as idiosyncratic summer catarrh, hyperesthetic rhinitis, periodic vasomotor coryza, vasomotor rhinitis, spasmodic catarrh, etc.

Its frequent association with asthmatic symptoms has created such terms as hay asthma, grass asthma, spasmodic rhinobronchitis. The word "pollinosis" has been suggested by Todd as most appropriate. Its meaning is self-explanatory.

Considerable advance has been made in recent years in the knowledge of the etiology and treatment of this disorder, so that there should exist a better understanding upon which to unite, in order to bring forth a name that will clearly describe the actual condition present, and at the same time a name that may be used internationally.

The term *periodic vasomotor coryza* has often been used to designate this condition and would be a most excellent descriptive title were it not for the word coryza, by which is usually understood a variety of acute rhinitis in which a rise of temperature is present, as well as other symptoms of infection, or trauma that do not obtain in hay fever *per se*. The word rhinitis might be substituted for coryza because in this sense it refers to a chronic variety that almost invariably is present. Otherwise the term is most acceptable, especially in the light of recent anatomical investigations, showing the intimate relationship between the fifth nerve that supplies sensation to the membrane of the nose, throat, and eyes, and the sympathetic nerve or its vasomotor branches.

For similar reasons the term *hyperesthetic rhinitis* might be used. The term indicates a superlatively sensitive nasal mucous membrane, and with the addition of the word "periodic" attention is directed to a type of hypersensitiveness due to some specific cause that occurs periodically.

Etiology.—It has been quite generally accepted that there are certain substances in the air that on coming in contact particularly with the mucous membrane of the nose, but also of the eyes and throat, of certain individuals precipitates an attack of this disorder.

Bostock, in 1819, seems to have been about the earliest observer to put on record the idea that some external irritating substance, like dust, heat, or extreme light was the cause of this trouble. After Bostock came Gordon, who, in 1829, ascribed the trouble to be due to the odor from flowering grasses. Many others believed in this theory of odor causation, even to our present time. Elliotson, in 1831, was the first really to ascribe to pollen the cause of the disorder, but it was the pollen of grasses and not hay that he believed it to be due to. Abbott Smith, in 1865, recorded his belief in timothy hay as a cause. Between 1865 and 1875 Phoebus, Morrill, Weyman, Pirrie, Moore, Beard, and others contributed much to the subject. To G. T. Gream may be accredited the observation that after a rain there was freedom from symptoms, and he therefore argued the cause to be fine dust. Blackley, of England, in 1872, made a very interesting investigation of the subject and succeeded in ascribing to seventy-four different pollen bearers an exciting action. Dunbar, of Hamburg, in 1902, published the results of conclusions following extensive investigation in this particular field of the subject. His opinion embraces the belief that a toxic substance is present in the pollen of certain plants that has a specific action in the production of this disorder. The investigations and experiments of Dunbar seem to show that it is the albuminous principle contained in the pollen that is toxic in character, and that constitutes the actual factor in the causation of hay fever, and that it is not due to any mechanical effect caused by the tiny spines and prickles that are often found on their surface, or to any pungent odor or essential oil they may contain. Not all plant pollen will cause hay fever. He and his "co-workers" have examined the pollen of 106 plants, and found them free from this action. Certain of the cereals, like wheat, rye, some of the flowers, and most all grasses will produce symptoms of the disease. Of grass pollens, he examined thirty-two varieties; they have smooth surfaces and no odor. Dunbar believes further consideration should be given to the idea that there may yet be discovered some substance existing in the fur of certain animals, like the horse, cat, and dog, that is concerned in the causation of the affection.

In America there are principally two varieties of this disorder—the spring and the summer varieties. The summer variety is the more prevalent and is caused chiefly by the goldenrod (solidago), ragweed (ambrosia), and the various asters, while the spring variety is caused by the grasses, of which the rye is perhaps the most common. It is peculiarly noteworthy that patients suffering from one of these two varieties are free from the other variety, although there is a class of patients who suffer from similar symptoms the year through, and appear to be susceptible to the action of all kinds of pollen.

It has as yet not been conclusively proven that all the various varieties of this so-called hay fever are caused by pollen, either as irritants or toxic substances, but from these and similar studies it can be said that some of the other theories regarding the etiology may safely be set aside and forgotten. This has reference in particular to the theory of odor causation, like the odor from animals, plants, essential oils, etc., and the theory of neurosis and psychic disorder.

Besides these, other theories have been advanced at various times, some of which at first appeared to offer the final solution of the long-lost cause. Principal among these was the theory of infection. Helmholtz, Heymann, and Sticker were all champions of this germ idea. Nothing more has been added to this particular theory that would strengthen its cause, alluring as it seems to be, and hence the conclusions respecting a specific bacterial infection must face still further investigation.

R. W. Allen,[1] in 1913, says: "In hay fever the stimulus to provoke the symptoms is occasionally a toxin of bacterial origin," and recommends active immunization by means of vaccine. He says: "In two or three instances I have isolated the bacillus septus in pure culture from the nose and by using 250 and 500 million doses of the autogenous vaccine secured complete immunity."

The combined vaccines for colds have been used also. Recently the procedure of ophthalmoreaction has been applied to determine the susceptibility to pollen toxin. Ellern[2] studied a series of thirteen cases tested by this reaction and treated by the pollen toxins. Therapeutically, he used one-fifth of the concentration used in the ophthalmoreaction, repeated every five days. Results were promising, although some symptoms appeared in all of the cases, but slight and not persisting. They averaged about six doses, beginning with 25 to 125 units and ending with 100 to 250 units.

Various areas within the nose have been definitely located by different authors from which the reflex originates, and they have advised the destruction of same by cautery, etc., but as a matter of fact the entire lining membrane is very sensitive.

Daly, of Pittsburgh, in 1881, created a new class of opinions, in that he laid emphasis on the internasal lesion as a most important factor in the causation. In this he was supported by Roe, Allen, Sajous, Hack, Hertzog, and others. Following this came John N. MacKenzie, 1884, championing the general neurotic character as the primal factor.

From 1884 to 1895 numerous authors (Molliere,

1884; Leflaine, 1887; Leseur, 1895; Cheatham, 1890; Bishop, 1894) expounded the theory of gouty diathesis and uric acid, hyperacidity of the blood, as causing hay fever.

All of these things just mentioned should be considered as provoking or exciting causes, but in order to create any symptoms they must affect an individual susceptible to their influence. Many individuals come in contact with some or all of the substances just described, but they do not necessarily exhibit any symptoms. This is due to their non-susceptibility. The matter of susceptibility is an important link in the etiological chain of this disorder and must be present before any symptoms are called forth. Just what constitutes this susceptibility is not as yet clearly defined, but from the evidence at hand it is reasonable to assume that it is one of disturbed metabolism. This disturbance in metabolism changes the body fluids, so that its effect, in turn, alters the physiologic state of the body tissues and makes them susceptible to various influences. The effect of such perverted metabolism on nerve tissue is to disturb its normal functional equilibrium. When a sensory nerve like the trifacial, with its immense area of peripheral distribution, is subjected to certain outward influences that act as irritants and excitants, there results a reflex action manifesting itself in a symptom-complex of varying assortment.

Now, these states of disturbed metabolism are more likely to occur in people of sedentary occupation, as students, teachers, accountants, etc., and these mental or nerve-exhausting duties are likely agents in creating a nervous or neurotic temperament, and together these two agencies may explain why this disorder is seen so frequently among this class of people instead of the active, out of-door worker, or in the one free from a surplus of nervous excitability. In this way can be explained the psychic variety of susceptibility, as illustrated in the case where the smell of an artificial rose or the picture of a rose may produce an attack.

Various ideas have been advanced by careful observers and experimenters as to what kind of a change was necessary to take place in the human laboratory in the metabolic processes that were constantly going on, in order to make such an impression on the nerve tissues of the body, so as to bring them under the baneful influence of certain specific irritants. One of the oldest and perhaps most popular theory of susceptibility is that of uricacidemia. Another is that of Michaels and D. B. Kyle, supporting the idea that chemical changes in the constituents of the mucus-secreting glands of the mouth bring about this susceptibility to local irritation. They are of the opinion that the body metabolism when perverted may give evidence of such by changing the saliva so as to show the presence of sulphocyanides, either the potassium or ammonium salt. Its reaction is also a consideration, whether excessively alkaline, excessively acid, or if neutral.

The term "idiosyncrasy," used so much in former days as expressive of a susceptibility to certain drugs, diseases, foods, and the like, is now more familiarly known to us under the caption of anaphylaxis. There is a disposition at this time to give credence to the belief that this anaphylactic condition is the predisposing element of hay fever. The subject has, as yet, not been given sufficient study by experimenters to venture a final opinion on the value of the information at hand.

I, myself, have been of the opinion, and have given voice to such opinion on several occasions,[3] that the disorder depends primarily upon a morbid state of the body fluids, principal of which is the blood. Some change in the chemistry of the blood takes place, which in turn leads to alteration in other fluids and membranes of the body, making them impressionable to the proper kind of irritant (pollen). Perhaps some ferment body introduced into the blood from some gland, or as the result of a metabolic process, which under favorable conditions excites the chemical change in the blood. I believe that further investigation in this direction will within a comparatively short time be rewarded by the discovery of the actual internal causative factor that is at the very foundation of this disorder.

Many other conditions, such as age, occupation, sex, geographical locality, altitude, climate, race, thermal changes, pathological changes within the nose, intranasal deformities, constitutional disease, etc., deserve a degree of consideration as possible secondary factors furthering or predisposing in nature. There is sufficient evidence at hand to warrant the belief that a fair number of cases presenting an associated sinus disease, or diseased middle turbinate, or a ridge, sharp spur, or deflected septum, may so increase the mucous membrane's susceptibility to the causal irritant that if removed or corrected the attacks are lessened in degree and number. Many a case of hay fever has been benefited by cauterization of the nasal mucous membrane, thus destroying in a degree its local susceptibility. And likewise considerable improvement may be expected where any permanent point of contact between septum and turbinates be fully corrected by removal of sufficient tissue to allow for normal ventilation and drainage.

Symptoms.—No one but an actual sufferer from this disorder can sufficiently appreciate the full measure of real discomfort, even real suffering, that the symptoms of this condition inflict. And even the afflicted one, when his term of suffering has ended, soon forgets the misery he has been a martyr to for so many months. In this respect he is much like the sufferer from neuralgia or from *mal de mer*. In all of these affections none other than the sufferer himself will ever know the agony that has been endured. The mere fact that the patients may otherwise appear well and that they have periods of intermission in which they are perfectly free from any distress whatsoever, and, finally, that their recovery is oftentimes very rapid, lends much to the support of the popular belief that the disturbance is of but little consequence.

The exact date of its appearance and its severity will depend in some degree upon the early or late season, and the amount of rain. The summer variety in America usually begins in the first week of August, the spring variety, the last of May or early June. Both last about two months.

The very earliest sign of an impending attack is a tickling within the nostrils and a sense of itching about the nose and cheeks and lips, and even other portions of the body. This itching of the skin sometimes is like a prickling sensation, although usually much like the brushing of a stray hair. Both of these sensations increase in frequency and intensity over a period of a day to several days before other symptoms present themselves. Finally, the tickling within the nostril becomes so intense that it provokes sudden and rather free watery discharge, and a succession of attacks of sneezing. The eyelids, particularly along the edge and at the inner canthus, begin to congest and cause annoying itching, often with excessive lacrymation and at times great intolerance to bright light. The itching is not always confined to the nose and eyelids, but often manifests itself in the roof of the mouth, the pharynx, and the faucial Eustachial tube openings. In the later stages of the disease it may be present in the trachea or bronchi, causing rasping coughing efforts. The frequency and intensity of the sneezing attacks vary in different individuals, and also in the same individual—sometimes the entire season may be passed through with very little sneezing, and again it increases to such an extent as to even cause great exhaustion and depression as well as cyanosis and unconsciousness in rare instances.

The discharge from the nose is serous in character

and, as a rule, very copious. But this, too, varies much. The patient may suddenly be seized by an itching of the skin about the face and a tickling within the nostril, and even before the explosive sneezing appears there may be such a profuse watery discharge from one or both nostrils as to require several handkerchiefs to take care of it. At times it is so profuse that it runs back into the nasopharynx. As the disorder progresses this watery discharge alternates with a mucopurulent discharge.

Frequently complaint is made of extreme stuffiness of one or both nostrils, so that free nasal breathing is interfered with. This stuffiness is due to a sudden turgescence of all the soft tissues within the nostrils. It is often astonishing how suddenly this may come on and equally suddenly disappear. At times it is only in one nostril, and perhaps so extreme as to actually cause a sense of painful pressure.

Owing to the congestion about the faucial tube, slight impairment of hearing with a sense of fullness may be present.

It is a curious fact that the symptoms are usually worse in the morning on arising. They also are worse when one is unoccupied or only slightly so, as in conversation, reading, writing, etc. Where one is very deeply or strenuously engaged in work, often hours go by without any of the annoying symptoms manifesting themselves, but if, after finishing this work, one should rest or read, or do some such less strenuous work, a perfect succession of stormy attacks may assail one.

The frequency and suddenness of the symptoms are exhausting and cause fatigue of body and depression of mind.

Occasionally the ordinary symptoms just mentioned, which are the ones found present in the greater number of cases, are supplemented by others that torment the already aggravated sufferer to his utmost endurance. One of the most frequent of these added tortures is asthma. This in itself is disturbing enough, but occurring in the presence of the hay fever syndrome it is most unfortunate. Some patients have on occasion been spared the usual nasal symptoms and instead have suffered only from the asthma. At times it seems that as a result of a succession of frequent explosions of symptoms a severe headache develops, that may continue to increase in intensity, so that it resembles attacks of head neuralgia. The intolerance to bright light sometimes becomes so great that the patient has to seek refuge in a dark room and remain there for days. This is more frequently so in young people. Very rarely have I seen any permanent injury to the eyesight, although scotoma is mentioned as being observed by some writers.

Treatment.—One of the greatest advances in the knowledge of hay fever has been made in respect to its treatment. Although no specific has been brought forth, yet some of the most recent recommendations as to the proper treatment have demonstrated their superior excellency in the greater number of cases. I firmly believe we are just now on the very threshold of solving the actual facts concerning the causes that bring about the manifestations of this disease, but until that knowledge is complete we must content ourselves with as rational application of the treatment as our present understanding will admit of; therefore much of the information relating to various drugs, methods and measures recommended by enthusiastic writers can safely be forgotten or remain unlearned, because of their almost universal uselessness.

The treatment may conveniently be considered under the following headings, namely: prophylactic, symptomatic and radical.

The Prophylactic Treatment.—Many have found that by going away each year just before the time for the attack they escape all or most of the disagreeable symptoms. In a general way, the seashore or mountains promise a safe haven. A sea voyage is beneficial, but not practical, because of the length of time the disorder lasts. In America the lakes of Maine, the White Mountains of New Hampshire, Northern Michigan, parts of Montana, Colorado, California, and Canada are the popular places to go to. The people affected in Germany and England usually go to Heligoland. The place to go to depends somewhat upon the variety of the affection. The Southern Coast of California has been highly recommended for the spring variety, while the White Mountains and Northern Michigan appear best suitable for the summer variety.

Where the patient is obliged to remain at home, then some measures should be taken to prepare him for his attack, and protect him from the external irritating cause. If distinct pathologic processes are present within the nose they should be corrected, if possible. Not that they are distinct causes, but, as pointed out before, in such nostrils the lining membrane is vastly more sensitive to any form of irritant. Hypertrophic inferior turbinates may with much benefit be cauterized with the electric cautery. Polypi and papillary hypertrophies along the edge or at the posterior ends of the inferior turbinates should be removed, as should also sharp spurs and large ridges of the septum. A markedly deflected septum should be straightened. Any existing sinus affection must be eradicated. The ethmoids and antra in particular should be carefully examined.

Several examinations of the blood, urine, saliva and mucus of the throat and nose will impart information as to the presence or absence of an acid intoxication. The presence of a more or less constant acidosis or an acetonemia indicates a morbid change in the chemistry of the body fluids, the result of a disturbance in the normal metabolism.

Correction of deficient elimination and imperfect digestion by a better diet, hygiene, habits and surroundings is of the greatest aid in furthering a correction of the disturbed metabolism. Dilute hydrochloric or nitromuriatic acid may be used with benefit.

If, by some practical way, a tolerance of the patient to the toxic pollen could be developed, then this disease would be robbed of much of its terror. This immunization of the susceptible person has received the serious attention of several investigators. Scheppegrell's method, whereby he claims to have achieved good results, has been to have the patient inhale, several times a day for several weeks prior to the time of attack, the pollen of the staminate flowers of ragweed. There seems much to be done yet in this direction before anything assuredly trustworthy can be offered to the sufferer.

Some years ago (1900) Holbrook Curtis advocated the employment of a fluid extract of ragweed as a means of procuring immunity, but the term of its popularity was short, it being replaced by a newer interest in an antitoxin brought out by Dunbar under the name of pollantin. This remedy has been on trial for several years and it has no doubt been used in great numbers of cases. The results from its use are as varying as the pollen-laden atmosphere itself that wafts the irritating stuff to the susceptible sinner's nose. Its best results are obtained where thought and time are given to the selection of the proper kind of antitoxin necessary in each case and the exact method of using it.

The Symptomatic Treatment.—This means virtually the treatment of the attack. Here we use, in addition to the means and measures enumerated under the prophylactic treatment, such drugs that have the action of benumbing, drying and shrinking the membrane of the nostrils. Cocaine is an old and well-known drug, but is mentioned only to be condemned, first, because of the very great dangers of creating the habit for its use, and, second, because, if efficient, it is only transitory. Several substitutes may be used that are less dangerous and whose beneficial effects

are more lasting than cocaine. Anesthone is such a preparation. Also anesthesin. Both of these used in paste or as an ointment are of great service.

Both the alpha and beta varieties of eucain may be used as a substitute for cocaine because of their lesser toxicity, but with no other advantage.

The drugs, alypin and stovaine, although anesthetic, should not be used because they congest the membrane and aggravate the stuffiness.

Antipyrine in two to four per cent. watery solution, applied as a fine spray following the application of cocaine or eucain, prolongs both the artificial anemia and the analgesia.

Atropine sulphate applied as a fine spray in the strength of $\frac{1}{100}$ grain to ʒi. water to the membrane of the nostrils several times a day will assist markedly in lessening the mucous discharge.

A combination of scopolamine and morphine in the strength of $\frac{1}{150}$ grain of the former and $\frac{1}{6}$ grain of the latter, giving only two such doses, one hour apart, will both dry and lessen the irritation of the membrane sufficiently to cause relief. In place of this the use of Bishop's coryza tablet may be used with benefit. It contains atropine sulphate, morphine, and caffeine. All such remedies as these should invariably be dispensed by the physician himself, and never given on a written prescription.

The various "rhinitis" remedies should be avoided, because the small amounts of quinine they may contain increase the uricacidemia; on the other hand, five to ten grain doses of quinine, have been of benefit.

Suprarenal preparations are useful in relieving stuffiness of the nostrils, but their effect is of very short duration. Adrenalin may be used in a solution in water in the strength of 1–8,000 to 1–5,000, and applied either by medicine dropper, fine spray, or cotton tampons, as frequently as desired.

A dusting powder containing the following:

Menthol	gr. i.
Sodii bicarb	gr. ii.
Magnesii carb	gr. iii.
Cocainæ hydrochlor	gr. iv.
Sacchari lactis	ʒ iss.

may be dispensed by the physician, but not on prescription, and its use as a snuff several times a day will result in marked relief.

Schadle (in 1907) and Fick were loud in their praise of the result received from the irrigation of the antrum of Highmore and the insufflation of aristol.

Heath (St. Paul, Minnesota) and Mohr (Mügeln) advocate nasal filters, made of fine mesh cloth stretched on a thin frame, the two connected by a spring and fitted and worn within the nostril as eye-glasses are worn on the nose. These little things are certainly a great comfort.

Dunbar advises the use of the toxin itself in making a diagnosis in doubtful cases. Those immune to the disease will not react, while those susceptible will under the application of the minutest part of the particular toxin, diagnosticum, respond promptly to an attack.

Watson Williams employs, at the very outset, thus preventing the attack, the use of a spray in the nose of a 1–50 or 1–20 biniodide of mercury solution. As it is painful, cocainization of the membrane first is best used, followed by a hypodermic of morphine. The pain and swelling disappear in several hours, and there follows a severe catarrh for three days. He also says Sir Andrew Clark advised painting the membrane with carbolic acid, quinine and perchloride of mercury. Denker has reported absolute cures from massage of the mucous membrane, and Fulton lauds the use of a spray containing a saturated solution of quinine sulphate, followed by an ointment of thirty grains of quinine to the ounce of vaseline.

If asthma is present the use of potassium iodide internally and adrenalin hypodermically is indicated.

The Radical Treatment.—It is almost an extravagance of speech to say there is a radical form of treatment for this disease, but from the clinical experience obtained in the light of our present knowledge, by methods sufficiently precise and thorough, one is justified in employing such a term as "radical." Arguing on the assumption that we are dealing with a disorder in which the nerve tissue has been made hypersensitive to certain external exciting agents by a perverted internal disturbance, and that the fifth nerve in particular, on account of its colossal peripheral distribution, is unduly exposed to this external agent, the idea of interrupting service between this nerve and the sympathetic system presents itself as a most rational method of procedure. This may be done in several ways. A most efficient and simple way is that first suggested and practised by myself in 1907 of nerve-blocking with alcohol. Sensation of the nose is furnished by branches from the first and second divisions of the trifacial nerve. The anterior nasal is a branch of the first and enters the nose through a foramen just in front of the most anterior olfactory nerve branch, and is distributed to the anterior one-third of the nostril. The remainder of the nose is supplied with sensation by branches from the sphenopalatine ganglion, which takes its origin in the main from the second division of the fifth nerve. Both of these nerve trunks can be reached at their point of exit into the nose. The anterior nerve enters at the side of the septum in the attic of the anterior nares at a place just posterior to the visceral wall of the frontal sinus. A lateral view skiagraph can be used, if so desired, although not necessary, to give the exact location. As is well-known, there is a great variation in the size and shape of the frontal sinuses; nevertheless, it has been found on taking the measurement of a great number of skulls that the location of the foramen for the passage of this nerve varies but slightly. A medium gauge needle, with a sharp point, but rather obtuse, and four inches long, is attached to a small syringe, and after cocainizing the area to be injected, five to seven drops of a sixty-five per cent. alcohol solution, made with freshly prepared sterile water, is slowly injected into the nerve at its foramen. This is done in both nostrils. If the nerves are properly injected, a characteristic pain immediately appears following the course of the nerve distribution. This pain may be anticipated and considerably mollified by the previous administration of a one-fourth grain morphine or codeine. Otherwise it may last for an hour or more. The addition of an anesthetizing drug to the alcohol I have not found of sufficient merit to use with regularity. Sluder advocates a five per cent. phenol in alcohol solution as an injection into the sphenopalatine ganglion for painful affections. Where these nerves have been effectually "blocked" it is customary to find the patient completely freed from all the distressing and annoying symptoms of the disease.

In some of the most intractable cases it is advisable to inject the posterior set of nerves in addition to the anterior ones. This set of nerves are reached at a point where they leave the sphenopalatine ganglion through the foramen and enter the posterior part of the nasal chamber. By using a special needle four inches long, of No. 18 gauge, curved at its distal end to about forty-five degrees, with a sharp but obtuse point, and fastened tightly to a small syringe, it may be hooked around the posterior end of the middle turbinate, forcing its point into the position of the nerve's exit.

The result sought for by nerve-blocking was also present in the minds of those who have advocated cutting or resecting the anterior ethmoidal nerve. Yonge, in 1908, described a method of dealing with severe cases of hay fever by resecting, under general anesthetic, both anterior nasal nerves at the anterior ethmoidal foramen. E. Blos later reported several cases operated on in this manner, with curative results.

I myself, already, in 1907, showed the possibility of reaching this same point with a trocar needle and injecting the nerve with alcohol.

The results obtained by such methods as these, where properly applied, invariably lead to a complete annihilation of all the head symptoms of the disease. The permanency of relief dwells entirely in the extent to which the degenerative changes occur. May ascertained experimentally that the effects of alcohol injected in a peripheral nerve cause a local necrosis of the nerve at the point of injection, and that this degeneration remains local and does not ascend. The anatomic continuity of the nerve favors rather rapid regeneration, although this return of function is held in abeyance by the fibrosis occasioned by the alcohol for sufficient length of time to carry the patient over the season. OTTO J. STEIN.

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Hays, Isaac Minis.—Born in Philadelphia, Penn., July 5, 1796. He entered the University of Pennsylvania in 1812, receiving his degree in the department of Arts in 1816. For the next year he devoted himself to mercantile life, but preferring to study medicine, he became an office pupil of Dr. Nathaniel Chapman, later entering the University of Pennsylvania from which he received his degree in 1820. He established himself in Philadelphia and became one of the brilliant group of eminent physicians in that city for which this period was noted. While doing general medicine, Hays devoted much of his time to eye conditions, becoming a pioneer in ophthalmic surgery and one of the most successful practitioners in America. He was appointed one of the surgeons to the Pennsylvania Infirmary for Diseases of the Eye and Ear in 1822, and at the foundation of the Wills Eye Hospital in 1834, he received the same appointment, which he held until 1854. He was one of the founders of the Franklin Institute, and its corresponding secretary from 1828 to 1840. At the foundation of the College of Physicians of Philadelphia, he was appointed chairman of the building committee, and he also played an important part in the organization of the American Medical Association, of which he was the first treasurer, and chairman of the committee which framed the Code of Ethics. In 1870 he assisted in the organizing of the Ophthalmological Society of Philadelphia and became its first president.

While Dr. Hays was noted for his work in ophthalmology his greatest fame rests on his career as a medical editor. In 1827 he became one of the editors of the *Philadelphia Journal of the Medical and Physical Sciences*. Later in the same year he was made editor and sole manager of the Journal and the name was changed to the *American Journal of the Medical Sciences*. He having devoted nearly fifty years of his life to this periodical retained this position until 1869. In 1833 he edited the *Cholera Gazette* and at the time of his death was the oldest editor in the United States. In 1843 he established the *Medical News* which he edited to the time of his death, and in 1874 began the publication of a *Monthly Abstract of Medical Science*, which was later merged with the *American Journal of the Medical Sciences*. He died on April 12, 1879.

Dr. Hays never published any original work in the form of books, but he contributed to an enormous extent to medical literature, through his editing and his contributions on various subjects to other men's publications. In 1829 he edited "Hoblyn's Dictionary of Terms Used in Medicine and the Collateral Sciences." He wrote the article on the eye in Dewees' "Practice of Medicine," 1833, and in 1843 edited Sir William Lawrence's "Treatise on the Diseases of the Eye." In 1834 he projected the American Cyclopedia of Practical Medicine and Surgery, a work which was stupendous and almost idealistic in its aim. The articles were to have been supplied by the most famous medical and surgical men of that time and the fact that it took almost two years for the publication of one volume, shows the scope of the entire work. As might be expected the plan was unsuccessful, because the time for such a work was not ripe, although Dr. Hays did everything in his power to bring about its success. E. L. J.

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